HOUSEHOLD WATER TREATMENT AND SAFE STORAGE IN GHANA:

AN INTERIM SOLUTION?

by

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A dissertation submitted to the Johns Hopkins University in conformity with the requirements for the degree of Doctor of Philosophy

Baltimore, Maryland

January, 2017

Abstract

Providing safe water to the poor in developing countries is a challenge that has persisted through decades of international development efforts, from the International Decade for Clean Drinking Water through the years of the Millennium Development Goals and now into the new age of the Sustainable Development Goals. The often-stated long-term goal of the water, sanitation and hygiene sector is to provide piped, treated water as a solution to this challenge. In the meantime, household water treatment and safe storage (HWTS) has been put forth as an interim solution that could be quickly scaled up. Critically, effectively scaling up HWTS requires achieving both coverage and uptake, meaning that HWTS must not only be made available to but also be used correctly and consistently by the target population in order to achieve improved health. This dissertation explores HWTS as an interim solution and the arguments for scaling-up HWTS to meet the immediate needs of populations currently without safe water. To do so, it considers HWTS from three different angles: as a concept in the literature, as products being sold and implemented, and as a national-level policy.

Chapter 2 reviews the literature on HWTS, identifying three key types of literature and the means by which HWTS has been evaluated over the past two decades. An impact evaluation of three influential publications highlights the prominence of both scientific and grey literature and the influence that they – and their authors – have on actors in the HWTS sector. Chapters 3 and 4 focus on the critical case of Ghana, a country that has made significant progress in increasing access to safe water but still suffers from a disparity among urban and rural, rich and poor within this improved access. Ghana has been the recipient of ongoing support (financial and otherwise) from

the World Health Organization (WHO) and the United Nations Children's Fund for the scale-up of HWTS in country, both with respect to implementing HWTS and developing HWTS-specific policy.

Chapter 3 investigates efforts to disseminate three HWTS products in Ghana, with an emphasis on both reaching vulnerable populations and on achieving scale through commercialization. The challenges and successes of these efforts highlight conflicts of interest with respect to reaching those most in need and achieving commercialization. Chapter 4 considers HWTS as a policy through an evaluation of Ghana's 2014 National Strategy for HWTS and its supporting documents. Tying in the experiences from the previous chapter and the current status of regulation in Ghana, this chapter explores the content of Ghana's HWTS policy and whether it effectively supports the scale-up of HWTS. Chapter 4 also takes into account the international context in which Ghana's policy exists and specifically considers the WHO International Scheme to Evaluate Household Water Treatment Technologies as a support tool for Ghana and whether it, too, effectively supports scale-up.

Throughout all three chapters, the arguments for HWTS as an interim solution that can rapidly reach scale create a common thread. Within this thread, a common assumption among proponents of scaling-up HWTS is that market strategies will facilitate this process. As highlighted in Chapter 3, however, the goals of providing safe water to vulnerable populations and achieving scale-up through commercialization often come in conflict, especially when considering the need to achieve coverage and uptake to improve health. The case studies, policy development and roll out in Ghana point to a need for continued, long-term commitment from the government, donors and NGOs if

HWTS is to be scaled up. If this is the case, HWTS is likely not an interim solution but a long term one. The conversation must shift to recognize this reality.

Acknowledgements

The completion of this dissertation was a true test of commitment – less so my commitment, more so the commitment of my advisors, mentors, friends and family to support me and love me unconditionally throughout the process. Without this love and support, I would surely not have persevered. My advisors Erica Schoenberger and Bill Ball had the confidence in me to give me freedom from the start to fully research and explore the landscape of water and sanitation in developing countries before committing to a topic. Their confidence in my ability to see my research through persisted when I myself was uncertain of my path and even when I got a job with CAWST and moved to Canada before completing my Ph.D. Their experience, insight, and ability to ask the right questions pushed me to think in new ways about important issues. I am thankful, as well, for the wonderful work environment at CAWST and the flexibility the organization provided when I was working to finish my dissertation in the summer.

I would be remiss if I did not also thank Kellogg Schwab for the opportunity to gain field experience in Ghana before setting out on my own and Melissa Opryszko for guiding that experience my first two trips to Ghana and for remaining a mentor and friend to this day. I must also thank then chair of the Dept. of Geography and Environmental Engineering (DoGEE), Ed Bouwer, for his unwavering support and his interest in all of my pursuits, be they academic or cabin-centric. My fellow students in DoGEE were a wonderful resource and support system, and I specifically want to thank Chris Kelley for all of the work he put into what became Chapter 2 and for being a friend throughout.

Over the course of the seven years I lived in Baltimore, I was fortunate to come to know so many incredible people – inside and outside of Hopkins – and to come to call them my friends. More specifically, I have recently come to reflect on just how many strong, driven, passionate women with whom I managed to surround myself. I met them through DoGEE, extracurricular Hopkins activities, Chesapeake Women's Rugby, November Project and CrossFit. These women explored and loved Baltimore with me and taught me about commitment to myself and to the people and causes I hold dear. Of these women, I must thank one specifically for her unique, positive, ongoing impact on my life. It is not possible for me to hold anyone in higher esteem than I do Andrea Staid, who has proven to be the best friend, teammate, roommate, colleague and mentor I could ever imagine. I must also mention my best friend, Zane C. Stone, who has also been a rock and a constant in my life since his arrival in Baltimore.

Finally, I would like to thank my family without whom none of this would have been possible. My parents have never doubted my ability to see this through – or at least never let on that they did – and have provided support to me in so many ways throughout the process. Among many things, my mom taught me to pursue my passion, but not at the sacrifice of my happiness, and my dad taught me that a good dissertation is a done dissertation. My brother has served as an example of taking time to learn what you love and then pursuing it wholeheartedly. His candor and goofiness are a bright light in my life. Among those who I call family are my cats Wheeler and Willough, who have brought such joy to me since their adoption, and Greg, my boyfriend, who has provided me with unwavering support, happiness and love over the past 15 months.

This work was funded by the Claire Boothe Luce Fellowship, the NDSEG Fellowhsip and the JHU Global Water Initiative and E^2SHI.

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1 Introduction

1.1 Access to Safe Drinking Water

1.1.1 Worldwide

In spite of the decades-long global response to the lack of access to safe drinking water, the problem persists. Although the water, sanitation and hygiene sector (WASH) sector has made significant progress over the past 15 years with respect to the Millennium Development Goals Target 7C, surpassing the goal to halve the number of people without access to safe water, many remain un-served. Furthermore, the indicator used to measure progress – access to an improved drinking water source – does not actually guarantee that water is safe upon collection, much less consumption. By definition, an improved source is simply that which is constructed in such a way that protects the water source from outside contamination, which means that anything from a piped household connection to a protected dug well qualifies.[1] A recent analysis that took into consideration the potential for source contamination estimated that 1.8 billion people worldwide rely on a drinking water source that is fecally contaminated. [2] One can imagine that the number would only grow if the potential for contamination during transport and storage were also included in this estimate.

Why does this matter? A 2014 analysis estimated that 502,000 people die due to water-related diarrheal disease resulting from lack of access to safe water; a disproportionate number of those dying are children under the age of five.[3] Although death is, of course, the most serious of outcomes, non-fatal illness due to water-related diseases also places a heavy burden on populations in developing countries, resulting in loss of productivity and medical expenses, among other things.[4] In short, this persistent problem has a persistent, negative impact on those living in developing countries.

1.1.2 Ghana

In later chapters, I will propose for reasons specific to a given chapter's argument that Ghana serves as a critical case. Here, I will simply introduce the situation in Ghana with respect to access to safe water. The country has made significant progress in increasing access to *improved* drinking water – it actually met target 7C of the Millennium Development Goals (MDGs) with respect to water, going from 56% of the population with access in 1990 to 78.6% in 2013.[5] But the country still has significant work ahead when it comes to achieving "universal and equitable access to safe and affordable drinking water for all" as set forth by the Sustainable Development Goals (SDGs).[6]

Looking at equitable access, disparity in access to improved water between urban and rural areas has decreased from 47% greater access in urban areas in 1990 to 16.4% greater in 2014. However, it is again important to note that access to improved water does not guarantee access to safe water at the point of use, where greater disparities persist. As of 2014, 16.9% of urban and only 1.7% of rural populations in Ghana had access to piped water into their dwelling, yard or plot.[7] This is where we can expect to find significant health benefits over other improved sources.[8] Furthermore, Ghana still experiences higher than average mortality rates for children under five years of age, due in part to the lack of access to an improved water supply and the resulting diarrheal disease. According to the World Health Organization (WHO), in 2015, the global under-five mortality rate was 43 deaths per 1,000 live births, and the rate in low-income countries was 76 per 1000.[9] The 2013 under-five mortality rate in Ghana was 78 deaths per 1,000 live births; at this time, an estimated 8% of the deaths of children under-five in Ghana were due to diarrheal disease.[10] The 2014 Demographic and Health Survey in Ghana found that 12% of children under five had diarrhea in the last two weeks. These statistics do not capture the impacts of chronic diarrhea for those who do not die, e.g. malnutrition and stunting, nor do they capture the morbidity and mortality due to water-related diseases outside of diarrhea, such as helminth infections.[11]

1.2 Household Water Treatment and Safe Storage

1.2.1 An Interim Solution

The oft-stated "long-term goal" of the WASH sector as a means to address the lack of access to safe water is centrally treated, piped water.[12,13] The key elements of this goal are: adequate treatment to achieve the required quality, which is dependent on source water quality; continuous, sufficient supply so that water does not have to be stored after collection and there is enough of it available to use for drinking, washing fruits and vegetables, and handwashing; safe storage, which in this case is provided by a well-maintained and pressurized distribution system that is continuously monitored and maintained as required; and tap-based distribution to the home, which not only solves the quantity problem but also that of ease of access.

While high-quality water at the tap is the norm in most developed countries (although one that is facing increasing challenges), the establishment of systems of centralized, piped treatment faces significant obstacles in developing countries, including high capital costs, challenges with government coordination and commitment, and increasing questioning of its efficiency of resource use and its long-term sustainability. Furthermore, developing countries often face economic challenges and prioritization that lead to compromised operation, maintenance and monitoring of existing systems.[14]

In urban areas, rapid population growth coupled with insufficient investments in improvement and expansion causes centralized systems to struggle to meet demand; this can result in intermittent access, which in turn leads to negative pressure that increases the potential for incursion of contamination through breaches in the system.[15,16] Some people may adjust to this intermittent supply by storing water, and the quality of the stored water can degrade significantly over time, especially if the storage container is dirty or does not protect against recontamination – i.e. does not have a cover and/or has a wide mouth.[17] Additionally, because of hidden infrastructure failures, households may use water from apparently successful systems that is actually hazardous to health.[18] In rural areas, populations are often very dispersed, sometimes over difficult terrain, making centralized, piped systems prohibitively expensive.[19] Because of these challenges, the WASH sector has worked toward alternative approaches to providing safe drinking water.

Since the 1990s, household water treatment and safe storage (HWTS) has received increased attention in the scientific and grey literature as a potential solution to the challenges faced by centralized, treated, piped water. Over the past two decades, a wide range of HWTS options has been developed. Among these, there are a number that have been found to remove microbial contaminants in the lab and field and to reduce diarrheal disease. Proponents argue that, beyond meeting these key criteria, HWTS is inexpensive, and would provide immediate – or at least accelerated – benefits while waiting for the longer-term solution of centralized treatment.[20,21,22,23,24] Supporters of HWTS also believe that these interventions can be simple and acceptable to end users.[25] Along these user-centric lines, HWTS has been set forth as a new paradigm in which end users are treated as consumers of a product as opposed to recipients of aid and can make a choice about which treatment option they want to use.[26] And proponents argue that, as a consumer product, there is the potential for HWTS to be scaled-up using for-profit production models, marketing strategies and distribution and supply chains. For these reasons, time and again in the scientific and grey literature as well as in formal and informal sector discussions, HWTS is being promoted as an interim solution to the lack of access to safe water.

1.2.2 A Brief History

Acknowledging the long-standing practice of boiling water as a form of treatment, the modern concept of household water treatment and safe storage emerged in the 1980s and 90s in a number of forms, through parallel efforts. In the early 1990s, the U.S. Centers for Disease Control and Prevention (CDC) developed the Safe Water System (SWS), a dilute, locally made chlorine solution used in combination with a safe storage container, in response to the cholera epidemic in Peru.[27,28] In responding to the epidemic, the CDC recognized that water supply, hygiene and sanitation interventions were not addressing what happens with water in the household, and the SWS was intended to address this gap.[29] The intervention was further developed and then implemented and studied in Bolivia, with the results of the first randomized, controlled trial (RCT) published by Rob Quick (of the CDC) and others in 1999.[30,31]

At the same time, Ronán Conroy of the Royal College of Surgeons in Ireland and others were studying SODIS in Kenya, with the first RCT results published in 1996.[32] The momentum from these studies led to more investigations into these and other forms of HWTS. SODIS was then taken up and championed by researchers at the Swiss Federal Institute of Aquatic Research and Technology (EAWAG).[33] Also in the early 1990s, David Manz of the University of Calgary began developing the biosand filter (BSF) and working in collaboration with the Center for Affordable Water and Sanitation Technology (CAWST) to implement and study this treatment method.[34] Ceramic filters were developed by Fernando Mazariegos in Nicaragua in the early 1980s, and were then picked up by Ron Rivera and Potters for Peace.[35] In 1998, Potters for Peace began to spread the ceramic pot filter globally by helping to set up production facilities in developing countries to be run by local partners.[36] The Procter and Gamble (P&G) Purifier of Water, a flocculant-disinfectant, was developed by P&G in collaboration with the CDC and launched in 2000.[37]

After a decade, there was a critical mass of researchers and stakeholders, leading to the inaugural meeting of the International Network to Promote HWTS (the Network), which was held in London in 2002.[38] The Network was officially established in 2003, and at the time was hosted solely by the World Health Organization (WHO). Today, the Network is co-hosted by the WHO and the UN Children's Fund (UNICEF), but its stated mission remains the same: "To contribute to a significant reduction in waterborne disease, especially among vulnerable populations, by promoting HWTS as a key component of water, sanitation and hygiene programs".[39] From the original 24 stakeholders, the Network now consists of 163 collaborating organizations, ranging from research universities and non-governmental organizations to for-profit companies and government ministries.[40] With the participation and input of these collaborating organizations, the Network works to move the sector forward and has set out specific targets to guide this progress, which will be presented in a subsequent section.

1.2.3 Proven Technologies

Of the above stakeholders, the CDC has remained a leading participant. In collaboration with the social marketing firm PSI (formerly known as Population Services International) and through other public and private partnerships, the CDC has implemented the SWS on a massive scale. As of 2013, SWS had been sold in more than 35 countries, with the total volume sold since 1998 sufficient to treat more than 137 billion liters of water.[41] But beyond its focus on a specific HWTS method, the CDC has contributed to the broader HWTS sector through its list of "proven" technologies in collaboration with USAID. To be on this list, a technology must have been found in independent studies to: (1) improve the microbiological quality of household water and (2) reduce the incidence of diarrhea in users.[42] This requires independent evaluation of a technology's performance in the lab as well as an RCT to measure its public health impact in the field.[43] The most recent release of this list was in November 2010, and the following technologies met the criteria at that time: household chlorination, ceramic filtration, slow sand (or biosand) filtration, SODIS, and flocculant/disinfectant.[44] Although it has been some time since this list has been updated, it continues to be referred to by those in the HWTS sector, and the 5 proven technologies still receive the most consistent attention in research and grey literature on the impact and scaling up of HWTS.

1.2.4 Sector Actors and Activities

HWTS technologies are often treated as black boxes. This is true not only in the traditional sense of a black box – simplicity is emphasized so that the user does not need to understand how or why it works – but also in the history of technology sense. The traditional focus has been on producing the technology and getting it into the field where it can be put to use saving lives, and more recently on evaluating the technology, not on the innovation-development process – the activities that have taken that technology from conception through development to production, distribution and implementation. And further, not on the HWTS sector that directs and drives this process, that motivates it, that supports it, that sees it through.

When we talk about the HWTS sector, though, to whom are we referring and what are they doing? For the purpose of this research, I break down the activities of the sector into three categories: research, practice and policy. These activities parallel the targets established by the Network in 2011, which are to achieve the following:

- **Research:** By 2015, an improved evidence-base demonstrating that HWTS interventions are effective and replicable with respect to achieving public health impact and long-term, widespread use;
- **Policy:** By 2015, 30 countries with established policies on HWTS; and
- **Practice:** By 2020, 50 countries with countrywide scale-up of HWTS.[45]

Although separating the sector's activities out into three areas makes them appear to be discrete, there are many overlaps among the three and layers of complexity within each. The same holds true for the actors who take part in these activities. Here, I will briefly attempt to describe the main set of actors in the HWTS sector and the activities they are involved in as well as point out examples of overlap among the actors and activities.

Developers and Producers

Behind every HWTS solution, there is someone who conceived of the product, whether starting from scratch or modifying an existing treatment method, and brought it into being. These actors take a product from conception through research to practice. Examples of such developers and producers were briefly discussed in the previous section on the history of HWTS. For the BSF, this was David Manz at the University of Calgary, who modified the traditional slow sand filter used in municipal water treatment to be of an appropriate scale for the household and to allow for intermittent use.[46] Jim Bodenner then took it a step further after meeting Manz and becoming enamored with the BSF; he pursued the independent testing of BSFs and obtained the rights to produce the BSF with a plastic housing as opposed to the traditional concrete housing.[47] Ceramic filters were developed by Fernando Mazariegos, but it wasn't until Ron Rivera and Potters for Peace picked them up that they began to be produced at scale.[48] Now, independent factories around the world, like Pure Home Water in Ghana (established by Susan Murcott of the Massachusetts Institute of Technology), produce ceramic filters. SODIS was developed and refined by researchers at EAWAG, led by Martin Wegelin, also known as "Mr. SODIS."[49,50] The Safe Water System was developed by the CDC, led by Medical Epidemiologist Rob Quick.[51] The P&G Purifier of Water™, a flocculant-disinfectant, was developed by Procter and Gamble, and championed by Greg Goodall, head of P&G's Children's Safe Drinking Water Program at the time. The original LifeStraw Filter from Vestergaard (a for-profit company now run by Mikkel Vestergaard-Frandsen) was the result of refining a simple tube filter designed in collaboration with the Carter Center as a part of its Guinea Worm eradication efforts.[52] And the list goes on.

Among these developers and producers, you find independent individuals, scientific researchers, non-governmental organizations (NGOs) and for profit companies. Regardless, behind each technology, you find at least one charismatic individual. This charismatic individual may be like Ron Rivera, whose organization Potters for Peace started with a different intention but quickly latched onto the local production and sale of ceramic pot filters as opposed to the local production of other ceramic products with the intention of selling them in the U.S.[53] As of 2012, there were 36 ceramic pot filter factories in 18 countries.[54] Or they could be like Jim Bodenner, a Michigan Rotarian, who first funded 10 concrete filters in the Dominican Republic (DR), which eventually turned into thousands. Soon enough, he was contacting the CDC to ask them to come audit the technology and Rotary's implementation activities in the DR. This, in turn, led his involvement in research through the commissioning of Mark Sobsey and others to perform randomized, controlled trials on the filters in Ghana, Cambodia and the DR.[55]

These individuals are passionate about the problem of safe water provision. They are also passionate about their HWT technology and getting it implemented in the field to be put into practice. Technology producers also want to sell their product, whether for a profit or simply to cover production costs and other expenses. With support from other groups of actors in the sector, HWTS producers repeatedly seek to do so through a commercial approach, which involves the generation of a market for HWT and the direct sale of products to end users. Recently, this has entailed incorporating commercial approaches into policy intended to support the scale-up of HWTS, and technology producers have been involved in the policy development process. And so, examples quickly emerge of the wide range of people who take part in the HWTS sector as developers and producers of technology and the ways in which they may take part in HWTS research, policy and practice.

Researchers

The field of HWT is an unusual one in that researchers are not just involved in the building blocks that may eventually be applied to the development of a specific HWTS product. An individual researcher may, over the innovation-development process of a product, be involved in its conception during bench scale experiments, development of prototypes of the product, testing of its efficacy in the lab once the product has been developed, evaluating its effectiveness in the field, measuring its public health impact through randomized, controlled trials, and exploring the uptake of the product in such trials and behavior change factors that influence this uptake. These researchers are not necessarily kept separate from the conditions they are trying to address, the people whose lives they hope to help improve, in the way that other research scientists may be, specifically those in medical fields. For example, my parents are molecular biologists that research the development of the pancreas in the fetus. The findings of their research become the building blocks of research on the nature and causes of diabetes, pancreatitis, and pancreatic cancer, which will hopefully in turn aid in the development of treatments and/or cures for these ailments. But never do they head up clinical trials, interact with patients, or go to where the patients live as part of their work.

An example of the potential for extensive involvement by researchers throughout the innovation-development process of an HWTS product can be found in the story of Rob Quick's role with the SWS. Quick is a Medical Epidemiologist in the Foodborne and Diarrheal Branch of the CDC. When the cholera epidemic struck in Peru, he and others at the CDC recognized that water supply, hygiene and sanitation interventions were not addressing what happens with water in the household.[56,57] To address this gap, they developed the SWS, a dilute, locally made chlorine solution used in combination with a safe storage container. Quick then went on to lead the implementation of the SWS in Bolivia and to head up the study of its impact, the results of which were published in the peer-reviewed journal Epidemiology & Infection in 1999.[58,59]

There are further examples of researcher involvement in the development of HWTS solutions. EAWAG researchers were behind the development and revision of SODIS as a form of HWTS, and they continue to be leaders in its study in both the lab and the field. In the world of ceramic filters, Susan Murcott, a senior lecturer in Civil and Environmental Engineering at the Massachusetts Institute of Technology, works with students to research different aspects of ceramic filter design and production to inform the operation of the Pure Home Water factory she has set up in Northern Ghana.[60] Justine Rayner, who is a PhD student of Assistant Professor Daniele Lantagne at Tufts University, is performing research on manufacturing variables and quality control in ceramic filter production and is leading the development of quality control guidelines and certification guidelines for filter factories.

David Manz, a hydraulics engineering professor at the University of Calgary at the time, developed the biosand filter (BSF) and led pilot implementations in Nicaragua.[61] Professor Mark Sobsey and his students at the University of North Carolina at Chapel Hill have carried out extensive lab- and field-based research on the performance of BSFs and have also carried out randomized, controlled trials of BSFs in the Dominican Republic, Honduras, Ghana and Cambodia.[62,63,64,65]

Because of their frequent, direct interaction with producers and implementers of HWTS and the significant overlap in their efforts with these actors, researchers are able to tailor their research to what they think is most applicable and useful. That said, some think that it is the implementers who are moving the field forward, moving ahead with what they are going to do, and the researchers sometimes must resort to playing catch up in testing the technologies to confirm that they do or do not work. The sense is that there are "a lot of passionate people who are going to move forward with or without research," and the best way to respond to this as a researcher is to focus on the questions that implementers are asking and aim to provide useful, practical answers.[66]

In an effort to summarize research findings and determine their implications for practice as well as to provide recommendations for future research directions, researchers may also perform and publish systematic reviews and meta-analyses of the research to date on HWT. Such publications help to compare the effectiveness of different HWT interventions or to compare HWT interventions with other WASH interventions. The findings of the individual studies themselves as to the effectiveness and public health impact of a HWT intervention or of the systematic reviews and meta-analyses may, in turn, be used by technology producers as supporting material for their products or by donors and policy makers such as WHO and UNICEF in supporting their backing of HWT as a public health intervention. Going a step further, researchers are sometimes commissioned by such entities as the WHO to write reports like Sobsey's 2002 *Managing water in the home: Accelerated health gains in improved water supply*. This publication has, in turn, been referenced by 82 peer-reviewed articles.[a] Researchers have also been called upon to develop guidelines that influence the decisions of donors and efforts of implementers, such as Brown and Sobsey's 2011 *Evaluating household water treatment options: Health-based targets and microbiological performance specifications*, developed for the WHO. From these brief examples, we are able to see the many different ways in which researchers are involved in the innovation-development process for HWTS.

Funders and Implementers

Outside of the sale of HWTS products directly to end users, the purchase and implementation of HWTS worldwide is funded by entities that range in size and affiliation, from large, international organizations to local NGOs to benevolent individuals. In Ghana, Pure Home Water together with its partners implemented over 15,000 ceramic filters from 2005-2010. During this period, UNICEF paid for 7,700 filters to be distributed in response to the floods in Northern Ghana from 2007-2008 and for another 4,000 filters in response to the Guinea Worm outbreak in 2008-2009.[67] In 2010,

[a] As tracked by the database Web of Science.

UNICEF purchased and distributed another several thousand filters through Pure Home Water.[68] From 2012-2013, Pure Home Water carried out two other large implementations: a 1,100-filter project funded by UNICEF and a 1,500-filter project funded by a group of Rotary Clubs.[69] Based on this information, the majority of the filters sold and distributed during this time were purchased in bulk and provided in blanket distributions, as opposed to sold commercially, directly to consumers.

Also in Ghana, Pastor Josephus Hallie donated his time to manage the distribution of plastic biosand filters for the U.S.-based nonprofit Safe Water Team. The main implementation that had taken place during Pastor Hallie's time with the Safe Water Team was funded by a Florida church congregation and by the Wishing Well International Foundation, a Florida-based non-profit.[70] Beth Devroy was also working to sell and distribute plastic biosand filters in Ghana. Although her initial efforts focused on direct sales to middle-class consumers, the majority of her (limited) sales were to wealthy individuals looking to send them to relatives in their home villages, to their alma mater, or to a local orphanage, for example. She also pursued corporate social responsibility sales to corporate foundations in Ghana, such as those for Cadbury and Unilever, as well as financing through carbon credits, with limited success.[71,72]

In Kenya, Vestergaard has been much more successful with respect to financing HWTS implementation through carbon credits, although the company had to invest $30 million of its own to initiate the project. In 2011, Vestergaard officially launched the Carbon for Water program and distributed 877,505 filters in the Western Province of Kenya. The program is ongoing, with plans to continue for 10 years total.[73] We'll explore all of the above examples in greater detail in a later chapter, but from these brief looks, it is clear that there is not only a wide range of implementers and the scales at which their working but also a wide range of the organizations and mechanisms used to fund HWTS implementation.

Policy Makers and Government Officials

The network of actors involved in policy development for and governing and regulation of HWTS is complex and consists of both international and local players. With respect to local players, the focus here will largely be on those involved at the national level, with some information on actors at the district and municipal level as provided by national-level actors.

On the international level, the entity that is leading the charge for development of national level strategies for HWTS in Ghana as well as a number of other countries is the Network, which is co-led by the WHO and UNICEF. In Ghana specifically, support from the Network has come in many forms. UNICEF provided funding to support the development of the National Strategy for HWTS (the Strategy), which covered the following key activities performed by international and local consultants: assessment of the status of HWTS in Ghana, development of a draft Strategy, finalization of the Strategy as well as development of the supporting documents for public private partnerships and scaling up, and Strategy dissemination workshops. The Network also provided support for the development of the Strategy through direct feedback in the writing and refining process as well as through its extensive involvement in and co-hosting of the West Africa Regional Workshop for HWTS Strategy Development, held in Ghana in May 2013. With the exception of participation by the HWTS Technical

Working Group, made up of representatives from relevant ministries and HWTS producers active in Ghana, efforts around strategy development have been consultant-driven and no funding has been provided to increase staffing or institutional capacity to aid in the rolling out of the strategy.

On the national level, a number of ministries and government entities are to be involved. For reasons that will be discussed later, the Environmental Health and Sanitation Directorate (EHSD) within the Ministry of Local Government and Rural Development (MLGRD) has been designated to lead efforts, but other key entities involved are: the Ministry of Water Resources, Works and Housing (MWRWH) and specifically within that the Water Directorate; the Community Water and Sanitation Agency (CWSA), which focuses on drinking water treatment and supply in rural areas and small towns; Ghana Water Company Limited (GWCL), which focuses on drinking water treatment and supply in urban areas; Ghana Standards Authority (GSA); the Ministry of Finance (MoF); the Ministry of Education (MoE) and Ghana Education Service (GES), and specifically the School Health Education Programme (SHEP); and the Ministry of Health (MoH) and Ghana Health Service (GHS).[74]

1.3 Scope

This dissertation will take a look at HWTS and the actors involved in its promotion from the three angles highlighted by the Network's targets: research, practice and policy.

Research: "By 2015, more credible and convincing evidence demonstrates that HWTS interventions are effective and replicable in terms of achieving long-term, widespread use and public health impact."[75]

Chapter 2 explores the conversation around HWTS that has taken place in the literature over the past couple of decades, looking not only at peer-reviewed, scientific publications but also grey literature. As is discussed in this chapter, although the peer-reviewed literature is looked to with regards to generating credible evidence, much of the convincing takes place in the grey literature. To set the stage, this chapter begins by identifying three key types of literature that will be the focus of the discussion: publications on randomized, controlled trials (RCTs); systematic reviews and meta-analyses; and grey literature. The first two of these types fall under the broader category of peer-reviewed publications. I then review the 4 basic criteria by which HWTS has been evaluated in the scientific literature: microbiological efficacy, microbiological effectiveness, public health impact and behavior change. These criteria show up throughout the conversation around HWTS in the grey literature as well.

The bulk of the analysis in Chapter 2 is on a collection of literature centered on RCTs of HWTS technologies. The methods section reviews how I identified the RCTs and generated the collection of literature around these RCTs. In establishing this collection, I define a sub-conversation on HWTS that I could explore to better understand knowledge creation and sharing and its effects on the conversation around HWTS. Within this collection, I identify the most cited RCT publication, systematic review and meta-analysis, and grey literature publication. An impact evaluation of these three influential publications highlights the prominence of both scientific and grey literature and the influence that they – and their authors – have on the conversation around HWTS, which in turn influences HWTS actors and activities.

Practice: "By 2020, 50 countries have achieved country-wide scale up of project-based HWTS."[76]

Chapter 3 investigates efforts to disseminate three HWTS products in Ghana: Vestergaard's LifeStraw Family 1.0, an ultramembrane filter; Hydraid, a plastic biosand filter; and the AfriClay filter, a locally-produced ceramic pot filter. Although these products differ in many ways - e.g. treatment technology, cost, manufacturer - the attempts to bring them to scale share two important goals: (1) reaching vulnerable populations; and (2) achieving scale through commercialization. The challenges and successes of these efforts highlight conflicts of interest with respect to reaching those most in need, effectively scaling-up and achieving commercialization. In the case of HWTS, effective scale-up means achieving not only coverage but also uptake – HWTS must not only be made available but must also be used correctly and consistently by the target population.

After presenting Ghana as a critical case for HWTS scale-up efforts, I introduce the three products of interest in Chapter 3, presenting information on their production, treatment mechanisms, specifications and performance. Having done so, I then review the fieldwork through which I obtained much of the information presented in this chapter, with the remaining information coming from an in-depth literature review that built off of Chapter 2. Given that the premise of this chapter – and the focus of the Network's target – is achieving scale up, I then explore the arguments behind scaling up HWTS before exploring two examples of achieving scale outside of Ghana: the Procter and Gamble

Children's Safe Drinking Water Program and the Vestregaard Carbon for Water campaign. Two key lessons emerge from these case studies. First, both of these programs have achieved large scale distribution of HWTS products, but it is unclear whether they have achieved uptake in addition to coverage. Second, although both programs are run by for-profit companies, neither achieved scale through commercialization. Having fully set the stage, the rest of Chapter 3 is dedicated to the Ghana-specific case studies, focusing on implementation activities in Ghana for each of the three products. The objective here is to learn from these efforts and identify challenges and limitations to scale-up in Ghana.

Policy: "By 2015, 30 countries have established policies on household water treatment and safe storage."

Chapter 4 considers HWTS as a policy through an evaluation of two sets of documents: (1) Ghana's 2014 National Strategy for HWTS (the Strategy) and its supporting documents; and (2) the WHO International Scheme to Evaluate Household Water Treatment Technologies (the Scheme) and the results of Round I. Tying in the experiences from the previous chapter, this chapter explores the content of these two sets of documents and whether they effectively support the scale-up of HWTS. First, I again argue that Ghana is a critical case, but in the policy context, and review the field work specific to this chapter.

From there, I dive straight into HWTS regulation and policy in Ghana. Before exploring the development and content of the Strategy and its supporting documents, I first introduce the reader to the state of the HWTS regulatory environment before the Strategy was established. I then present an overview of the strategy development process and review the basics of the content of the Strategy and its supporting documents. This sets the stage to dive deeper into some of the key points and discuss their strengths and weaknesses. These key points are defining HWTS as a behavior and relying upon private sector participation; the latter involves consideration of regulation, financing, and subsidies. Finally, I address the elephant in the room – competition from sachet water – and discuss what can be learned from its rapid scale-up.

The second part of Chapter 4 is dedicated to the WHO Scheme and the results of Round I of testing under the Scheme. To begin, I provide some background on the Scheme and two important documents that came before it and contributed to its final form. I then present the basics of the Scheme and its evaluation of HWTS products, which in its current form largely focuses on pathogen inactivation or removal, based on a tiered system of microbiological performance targets. This evaluation process was applied to 10 products in Round I, and I briefly review the results along with some of the more general content in the Round I report around the Scheme and its application. My fieldwork provided an opportunity to gather and observe reactions to the Scheme from those in the HWTS sector, which I summarize here.

Chapter 5 summarizes the findings and conclusions of each of the body chapters. I then present overarching conclusions that tie the dissertation together.

2 Research: Systematic Review and Analysis of the HWTS Literature

"By 2015, more credible and convincing evidence demonstrates that HWTS interventions are effective and replicable in terms of achieving long-term, widespread use and public health impact."[77]

2.1 Background

Providing safe water is easy. Providing sufficient safe water consistently to poor people is difficult, as proven time and again. From the Millennium Development Goals to the Sustainable Development Goals, this problem persists, as does the discussion on how to solve it. Household water treatment and safe storage (HWTS) has been proposed as a solution for populations without safe drinking water, and as a result, a conversation has formed around HWTS. There is a wide array of actors who take part in this conversation – technology developers and producers, researchers and academic institutions, implementers and funders, and policy makers and government officials, to name a few. Much of this conversation takes place in high-level meetings, over coffee at conferences, or on the road to an implementation site, in situations where knowledge created and exchanged is not effectively captured for future sharing and conversation.

At the same time, a lot of this conversation is actually captured in the literature produced and then consumed by these actors. This literature forms the base on which the formal conversation around HWTS is built, and new literature shifts the content and direction of the conversation. This formal conversation influences the informal conversations that take place outside of the literature and influences the actions and decisions taken by the different actors. As a result, examination of the HWTS literature can be a valuable means of exploring knowledge creation and diffusion within the sector and how it influences the course of the conversation.

Scientific research is a vibrant part of the HWTS sector, and the peer-reviewed literature on this research contributes significantly to the conversation, contributing to a sense that the sector relies upon evidence-based decision-making and best practices captured in this literature. I maintain, however, that the influence of scientific literature on this conversation is rivaled by that of grey literature produced by other actors, or even by researchers themselves. Further, I will argue that the knowledge being created and shared by this latter type of literature is not being effectively verified and documented and at times is cited in an incorrect or misleading way. Given the prominence of literature in the conversation, the influence it has on actors in the HWTS sector, and the opportunity it provides to capture and share knowledge within sector and with related sectors, it is important that we better understand what knowledge the different types of literature create and capture how they contribute to the conversation.

2.1.1 Scope

This chapter consists of two parts. The first part, contained in sections 1 and 2, is a literature review. In Section 1, I explore examples of how the actors introduced in Chapter 1 produce, interact with and rely upon HWTS literature. I then identify three key types of literature within the conversation on HWTS, followed by describing the four main ways that HWTS is evaluated in the scientific literature and presenting the key findings for each of these evaluation criteria. In Section 2, I briefly explain the methods used to establish the collection of literature to analyze and the ways in which I attempted to explore this collection. The collection of literature is used here for a textual analysis to explore broader trends in the literature as well as in Section 3 to perform an impact evaluation and citation analysis of the most highly cited literature.

Section 3, the impact evaluation and citation analysis, and Section 4, the conclusion, make up the second part of this chapter, which focuses on the most highly cited of the three types of literature. By identifying the key findings and/or content of each of these three publications, tracking the way in which they are cited, and comparing the two, I evaluate the influence they have on the literature and on the conversation around HWTS that takes place outside of the literature.

2.1.2 Actors and the Literature

Here, I provide some examples of how each actor may generate and engage with literature on HWTS before I move on to focus on the three types of literature of interest. The list of examples is far from exhaustive because, as was shown in Chapter 1, the overlap between the different groups of actors and the many ways in which they interact with other actors creates a very complex network of collaboration and communication, producing, in turn, a wide array of literature.

Developers and Producers

The developer/producer of a HWTS product will generate a variety of literature, including user manuals, reports on results of laboratory tests, white papers and promotional materials. Their product idea may be influenced by literature they have read on other products. In an effort to establish the efficacy and effectiveness of their product, they may engage with researchers to perform lab and field studies on the performance and health impact of their product, the results of which may turn into a white paper or a publication in a peer-reviewed journal.

Researchers

The researcher is driven to undertake research that is usually hypothesis-driven and evidence-based, often collecting their own data from the laboratory, the field or both. They will generate results and findings that are usually (ideally) published in peer-reviewed journals, sometimes working with developer/producers and Non-governmental Organizations (NGOs) in the process. They may also be commissioned by International Organizations (IOs) to write high-level reports and/or policy-focused publications that are not intended for academic outlets and that are not-peer-reviewed, or they may be engaged by policy makers and government officials to participate in the writing of policies, strategies and regulations.

Implementers and Funders

NGO staff may look to the literature generated by developers/producers and researchers when considering what HWTS product to implement and how; their decisions will likely be influenced by existing regulations on HWTS where they are working. They may work with researchers or other organizations to evaluate the impact of their implementations, the results of which may turn into reports or peer-reviewed publications. Donors – whether companies, foundations, individuals, NGOs or IOs, to name a few – are able to consider all of the previously mentioned literature when deciding what product, intervention, and/or organization to fund. In the case of IOs such as the United Nations Children's Fund (UNICEF) and the World Health Organization (WHO), staff may work with policy makers and government officials to support the establishment of policies and regulations. They may also write high-level and/or policy-focused literature of their own or produce written recommendations for policy makers and government officials or NGOs.

Policy Makers and Government Officials

In establishing policies and regulations – and generating the associated literature – policy makers and government officials may turn to research findings, such as those on the effectiveness of HWTS in improving the microbial quality of water and reducing diarrheal disease. They may also look to documentation, policies and regulations from other countries or reports from NGOs on the implementation of HWTS. With respect to determining whether to allow a specific product to be imported into their country, they may rely on the results of independent testing of the product and recommendations from IOs regarding minimum acceptable levels of performance and other evaluation criteria.

2.1.3 Types of Literature

In this chapter, I explore the literature on HWTS and how it shapes the conversation around HWTS. Toward this end, I will be focusing on three types of literature: (1) publications on randomized, controlled trials; (2) systematic reviews and meta-analyses; and (3) grey literature. In this section, I establish the basics on these three types of literature and how they fit into the conversation around HWTS.

Publications on Randomized, Controlled Trials

Simply put, a randomized, controlled trial (RCT) is a trial in which there are two groups – the intervention group and the control group – into which participants, whether individuals, households, or communities, are randomly assigned. The intervention group is that which receives the intervention that is being tested – for example, a vaccine, a bed net, or a household water filter. The control group does not receive the intervention. In well-designed health trials, the control group will receive a placebo that is intended to be perceived as the intervention itself, such as a sugar pill that looks the same as the medication (intervention) that is being tested. This perceived sameness is critical for blinding the trial. For the purposes of minimizing bias, double blinding is ideal, meaning that neither the recipient nor the deliverers know which recipients receive interventions and which receive placebos. The use of the double-blinded RCT as the "gold standard" for generating high quality evidence originated in the medical sector but has since spread to other sectors.[78]

In HWTS literature, the RCT is often referred to as the "gold standard" of epidemiology and health interventions, but without the qualification that it be double-blinded.[79,80,81] In HWTS trials, blinding is difficult, in part because HWTS interventions cannot be hidden from participants or investigators.[82] There have been a couple instances in which the control group received a placebo, and the study can therefore be double-blinded.[83,84] But in the case of the one such trial performed in a developing country, the sham filter removed microbiological contamination, making it an alternative intervention instead of a placebo.[85] This instance serves as an example of the challenge of developing a placebo filter that improves the appearance of the water as if it were an effective filter but does not remove microbiological contamination.

As a result of these and other challenges, the control groups in the majority of HWTS trials receive nothing, meaning the trials are unblinded.[86] This has led some to caution against the use of the term “gold standard,” particularly because these unblinded RCTs on HWTS often rely on self-reporting of diarrheal disease, opening these trials up to potential reporting bias.[87] An additional concern is ethical, in the sense that the benefits of effective water treatment are known to exist, and so delivery of a non-functional device may do real harm. Recently, there have been an increasing number of calls for blinded HWTS trials, but because of the challenges and concerns, unblinded RCTs remain the highest standard of practice in most cases.

Systematic Review and Meta-analysis

As with the double-blinded RCT, the systematic review has long been held in high regard in the medical sector sector, but in this case as related to the identification and selection of appropriate interventions for promotion and further testing. This emphasis has since spread to other sectors, including the WASH sector.[88] By setting out a clear, systematic process of searching for, evaluating, and selecting qualifying studies for review before beginning, systematic reviews aim to avoid selection bias. This differs from a narrative review, which is descriptive, for the most part, and is less systematic and comprehensive in regard to selection of studies for review – rather, selection is more subjective and often at the sole discretion of the author(s).[89] Because of the extensive, well-documented net that a systematic review casts, it is replicable. Further, when high standards regarding study design and data quality are used for study selection, the review results tend to be more reliable and less uncertain.

Systematic reviews are often accompanied by a meta-analysis of the results of the selected studies. This analysis relies upon statistical methods to combine and analyze the data from the studies to provide "a single quantitative estimate or summary effect size," with the effect size informing the reader as to the magnitude of the intervention's (e.g. household chlorination of stored water) impact (e.g. reduction in diarrheal disease).[90] Together, a systematic review and meta-analysis provide a qualitative and quantitative summary of the status of and recent developments in the selected research area represented by the literature.

Grey Literature

Grey literature is, essentially, literature that is produced by government, academics, industry and business entities that are not commercial publishers, meaning that publishing is not the entity's primary activity. Although information that is published in grey literature is not always (or perhaps even often) passed through the formal peer-review process that articles on RCTs and systematic reviews and meta-analyses published in academic journals go through, it is sometimes reviewed by teams of others. In this regard, one further qualification that may be included in the definition of grey literature by some (including myself in this chapter) is that it is "of sufficient quality to be collected and preserved by libraries and institutional repositories."[91] Along these lines, use of the term “grey literature” throughout this chapter is not intended to imply a necessarily lower quality of information.

For the purpose of this study, the grey literature I am interested in exploring comprises publications from established, respected IOs and NGOs that meet a certain standard of publication – i.e. use of citations – and reach a broad audience. It is of note, however, that there is no guarantee that this literature has been formally reviewed and approved by individuals other than the authors and their associates.

2.1.4 Evaluation of HWTS

The published HWTS RCT literature focuses for the most part on the public health impact of interventions, and most often on the reduction of diarrheal disease; however, they may also consider other aspects – for example, uptake or use of an intervention. Within publications on RCTs and other scientific literature on HWTS, evaluation criteria can be categorized into 4 different areas: microbiological efficacy, microbiological effectiveness, public health impact and behavior change. Below, I briefly review these four areas so that they are familiar when they arise in the results and discussion section.

In the subsequent analysis of the HWTS literature, I focus on the literature evaluating the five “proven household water treatment options,” as set forth by the U.S. Centers for Disease Control and Prevention (CDC) and USAID. These 5 options are those that have been found in RCTs to: (1) improve the microbiological quality of household water and (2) reduce the incidence of diarrhea in users.[92] They are:

- Chlorination

- Flocculation-disinfection
- Ceramic filtration
- Biosand filtration
- Solar disinfection (SODIS)

Although these are currently discussed as the "proven" methods, boiling remains the most widely practiced method.[93] Furthermore, there are other methods, such as membrane filtration, that have since been similarly tested and found to be effective, such that they may also merit being considered for addition to the list. For reasons discussed further in the Methods section, however, I focus on the above five methods.

Microbiological Efficacy

A basic means of evaluating HWTS methods is the determination of whether a given method is microbiologically efficacious. That is, does it remove and/or inactivate microbiological contamination – does it do what it is supposed to do – under controlled conditions, in the laboratory, when used by a researcher trained on its operation and maintenance? If a method does not achieve desired levels of removal in this setting, it certainly cannot be expected to do so in the field, under variable conditions, when used by the intended end user who may not be trained on its operation and maintenance.

In regard to the common goal of removing pathogens, which is the primary and often only focus of HWTS, the question is one of microbial efficacy. Answering this question has long been, and continues to be, the first step in determining whether a technology should be moved forward. Before investing money in RCTs to determine whether a HWTS product is effective and has the desired public health impact (assuming the producer intends on taking these steps), it would make sense to first test the product in the lab to determine whether it is microbiologically efficacious.

To evaluate microbiological performance, most HWTS studies have focused on the three most common types of pathogens: bacteria, viruses and protozoa. These three pathogen classes can be found in drinking water supplies that have been contaminated by animal and/or human feces (WHO 2016).[94] Furthermore, specific pathogens from each of these three classes – rotavirus, *Cryptosporidium*, and certain strains of *Escherichia coli* – were recently found to be at the top of the list pathogens associated with moderate to severe diarrhea in over 20,000 children living in developing countries (Kotloff et al. 2013). In the testing protocol established in the WHO International Scheme to Evaluate Household Water Treatment Technologies (the Scheme), specific reference organisms are designated for testing (See Table 1). The standards established in this protocol are very high, with complex and expensive procedures. The WHO has recognized this and is working to simplify the protocols and lower testing costs while still using the chosen reference organisms.[95] Studies on microbiological efficacy will often use different reference organisms or materials (e.g. fluorescent microbeads to represent *Cryptosporidium oocysts*), and few studies test for all three pathogen classes, largely because of financial and time constraints.

Table 1. Microbial groups

Pathogen Class	Reference Organism
Bacteria	*Escherichia coli*
Viruses	MS-2 coliphage; phiX-174 coliphage
Protozoa	*Cryptosporidium parvum*

Results of microbiological testing on the 5 HWTS methods are presented in Table 2 below. One can observe that, in most cases, the numbers for a given HWTS option are taken from several sources; in some cases these numbers are presented as ranges, in others as one number. Additionally, numbers are not available for all pathogen classes for all HWTS methods. This presentation is intentional and is reflective of the different manner in which results have been presented in the cited literature. Furthermore, the conditions of testing differ from study to study, including combinations of ideal laboratory settings, conditions designed to simulate typical field conditions, and so-called "challenge" conditions that are designed to mimic especially high-concentration influents or difficult field situations.[96, 97]

Table 2. Measured Microbiological Efficacy of HWTS Options

	Percent Removal		
HWTS Method	**Bacteria**	**Viruses**	**Protozoa**
Chlorination	99.99%[98]	99.99%[99,100]	99.9%[101,102]
P&G Purifier of Water[103]	≥ 99%	≥ 99.9%	≥ 99%
Ceramic Filtration[104]	99.96 - 99.999%	68.4 - 87.4%	Not Available
Biosand Filtration	98.7%[105,106]	85.9%[107]	99.88%[108]
SODIS	>99.999%[109]	99.9-99.99%[110]	90 - 99.99%[111,112]

Microbiological Effectiveness

Establishing the microbiological efficacy of a HWTS option does not guarantee that it will achieve significant, much less equivalent, level of removal under real conditions during daily use by the intended end user. When considering actual performance in the field, one must take into account not only the varying quality of source water but also the skill level of the person using the treatment technology, the conditions under which he or she is operating, and the support he or she has in the system's operation and maintenance.[113] These are just a few of many factors that come into play when a technology is used in the field.

Given the variability inherent in these factors, HWTS performance can also vary considerably. Some of these determining factors can be tested in the laboratory, but the ultimate conditions most relevant to field use can be hard to ascertain. With SODIS, for example, the duration of sun exposure and the turbidity of source water are location-dependent variables that can dramatically affect the effectiveness of treatment. Similarly, turbidity and actual contact time (as controlled by the end user) are key determinants of the quality of water treated by chlorination and flocculation-disinfection.

The potential impact of such factors on HWTS effectiveness can be seen in Table 3 below, in which I present the estimated baseline and maximum effectiveness from Sobsey et al. 2008. The authors define baseline effectiveness as the expected performance in the field when a relatively unskilled person uses a given HWTS option to treat water of varying quality with minimal support for optimizing treatment conditions and practices. Maximum effectiveness, on the other hand, is when a skilled operator uses the HWTS option to treat water of "predictable and unchanging quality" with the support needed to achieve and maintain the highest level of performance. In short, one could roughly summarize the two as being actual performance and ideal performance or even, essentially, effectiveness versus efficacy.[114] The difference between the two is stark across all five HWTS option and all three pathogen classes.

Table 3. Estimated Baseline and Maximum Microbiological Effectiveness of HWTS Options

HWTS Method	Pathogen	Baseline LRV[b]	Maximum LRV	Measured LRV
Chlorination	Bacteria	3	6+	0.7[115]
	Viruses	3	6+	Not Available
	Protozoa	3	5+	Not Available
Flocculation-disinfection	Bacteria	7	9	Not Available
	Viruses	2 – 4.5	6	Not Available
	Protozoa	3	5	Not Available
Ceramic Filtration	Bacteria	2	6	1.3+[116]
	Viruses	0.5	4	Not Available
	Protozoa	4	6	Not Available
Biosand Filtration	Bacteria	1	3	0.8 – 0.9[117]
	Viruses	0.5	3	Not Available
	Protozoa	2	4	Not Available
SODIS	Bacteria	3	5.5+	1.1 – 2.2[118]
	Viruses	2	4+	Not Available
	Protozoa	1	3+	Not Available

Effectiveness also ranges within a given HWTS option. For locally produced filters such as ceramic pot filters and biosand filters, this could reflect the effect of numerous factors that may not be captured by testing a small number of units in the lab. For example, a study on ceramic pot filters by Rayner et al. (2013) found that the manufacturing factors – "consistency of materials, manufacturing methods, and quality control practices" – can vary considerably not only between factories but within a single factory (p. 252). In addition to differing initial levels of removal among filters, any given filter's performance may decline over time, due not only to variations in manufacturing but also other factors such as improper maintenance and location-specific factors that vary from community to community.[119, 120] Varying performance has been found to be an issue not only with locally produced HWTS options but also with centrally produced units.[121]

[b] LRV = $\log_{10}$ reduction value = $\log_{10}$ (pretreatment concentration) - $\log_{10}$ (post-treatment concentration)

Not only is effectiveness hard to achieve, it is also a challenge to measure. The conditions that make it difficult to achieve maximum effectiveness also make it difficult to measure this effectiveness. In the field, the removal of viruses and protozoa is rarely, if ever, measured. For bacteria, *E. coli* is sometimes measured using methods that involve visual determination (e.g. presence/absence or fluorescence), but often fecal coliforms are measured instead as a proxy for *E. coli*. Furthermore, in the case of field studies, effectiveness is not always measured as percent removal; for example, it's sometimes measured as the percentage of samples that did not test positive for fecal coliforms. In the final column of Table 3, I've included some examples of measured effectiveness of the different HWTS options from the literature. Note that, in all instances, these measured values are lower even than the estimated baseline effectiveness from Sobsey et al. 2008.

An additional concern in regard to ultimate effectiveness is that of storage. Even if a treatment method is microbiologically effective at the time of treatment, there remains the chance that water will be recontaminated before consumption. There are treatment methods that provide protection against recontamination through residual chlorine that remains after treatment to prevent microbiological growth during storage (e.g. chlorination, flocculation-disinfection). For methods of treatment that lack residual protection (e.g. SODIS, ceramic filtration, biosand filtration), this is an issue of major concern. One example where such concerns have been specifically identified and measured is in a study conducted by Fiore et al. in Nicaragua. In this study, the authors showed that recontamination reduced the final bacterial removal efficiency of biosand filters (from source to storage) in Nicaragua from 80% to 48%.[122] More generally, it is widely appreciated that unsafe storage and handling can lead to recontamination.[123] This possibility is addressed directly by the basic design of a ceramic filter, which has safe storage built in, and studies have shown this design to provide benefits in final effectiveness.[124] Similarly, the means of performing SODIS – storing water in clear, plastic bottles – provides users with safe storage as well.

For methods that do not have built-in safe storage (e.g. chlorination, P&G Purifier of Water, biosand filtration), safe storage is an additional measure to protect against recontamination. Safe water storage containers should: (1) have an opening that is covered or closed with a lid and small enough that it prevents users from inserting hands, ladles, cups or other possibly contaminated items into the water; (2) have a small opening or tap/spigot that provides easy access to stored water without necessitating the use of hands or other objects to collect water; and (3) be appropriately sized for the HWTS method.[125]

For methods that do not include safe storage and interventions that do not provide containers, the initiative to procure one is passed on to the end user. Concerns over recontamination due to lack of residual disinfectant and/or improper handling and storage have led some to recommend drawing from the concept of multiple barriers used in centralized water treatment plants. Proponents of this multiple barrier approach suggest that treatments without residual protection should be followed by chlorination and safe storage.[126]

Public Health Impact

Microbiological effectiveness moves evaluation from the lab to the field, but the next step to determining the potential impact of an HWTS intervention is to explore its effect on the health of those who are using it. There are different types of epidemiological studies that can be used to measure health impact, but again, RCTs are looked at with the highest regard. As mentioned above, the 5 proven HWTS options have been found not only to effectively remove microbiological contaminants but also to reduce diarrheal disease in RCTs.[127, 128] And as has been found with respect to microbiological effectiveness, diarrheal disease reduction ranges both within and among HWTS methods and is dependent on many technical, environmental, cultural and behavioral factors. The most recent estimates of the pooled effects of the 5 HWTS options from the 2015 meta-analysis by Clasen et al. are presented in Table 4 below.[129]

Table 4. Diarrheal Disease Impact of HWTS Options

HWTS Option	Diarrheal Disease Reduction (95% CI)
Chlorination	23% (9% - 35%)
P&G Purifier of Water	31% (18% - 42%)
Ceramic Filtration	61% (47% - 72%)
Biosand Filtration	53% (43% - 61%)
SODIS	38% (6% - 58%)

Examination of Table 4 reveals that these interventions can have a significant impact on diarrheal disease during field studies. It has been found, however, that this beneficial impact decreases with increasing study duration. In a 2009 analysis of HWTS studies of different durations and their findings with respect to public health impact, Hunter found that the relative risk of diarrheal disease in the intervention group increases for all treatment types as study duration increases, which means that the reduction in risk of diarrheal disease decreases over time.[130] Potential reasons for this attenuation include a decrease in microbiological effectiveness, as was discussed in the previous section regarding locally produced filters. Additionally, correct, consistent, continuous use has been found to influence public health impact and is discussed further in the following section.[131, 132, 133, 134, 135]

Behavior Change: Correct, Consistent, Continuous Use

Unlike treated, piped water delivered directly to a tap in the home, HWTS requires additional behavior change in order to ensure that water is safe at the point of consumption. This behavior change has been represented by a number of terms in the literature, including uptake, compliance and adherence. Of the different terms, I prefer the "three C's" – correct, consistent and continuous use.[136] Regardless, all of these terms are trying to capture the following: is a household – all of its members – using the intervention correctly to treat its water, regularly to ensure that treated water is consistently available to all members, and continuously regardless of the water source, water availability or season; this includes safe storage and other behaviors to avoid recontamination as well as avoiding drinking untreated water. With each of these requirements comes the opportunity for "non-compliance", which has been found to reduce microbiological effectiveness and public health impact.[137]

Correct use of a HWTS technology requires the knowledge of how and ability to operate it correctly. The end user must also be able to maintain the technology as well as replace parts or the whole unit if anything breaks (in the case of durable HWTS solutions, as opposed to consumable solutions like chlorine). In the case of ceramic water filters, both regular cleaning of the filter and the availability of replacement parts have been found to increase the chances that low diarrheal rates are achieved.[138] In contrast, limited availability of the plastic bottles needed for SODIS has been found to hinder its successful implementation.[139] There is interplay between all of these factors: ability to use and maintain a filter correctly can increase its longevity; correct dosing can reduce wastage and increase how long a consumable product lasts. In addition to the ability to use a technology correctly, technical factors may also influence the willingness of end users to make the behavior changes necessary to achieve compliance, as such factors can play into how easy a technology is to use.

Ease of use ties correct use together with consistent, continuous use, as a technology must not only be easy to use in order to produce water that is safe to consume but also to encourage consistent, continuous use by being convenient – that is, not taking too much time or energy. In fact, it has been found that user satisfaction is driven more by an increase in convenience due to technical improvements than by perceived health benefits.[140] In some studies, respondents have cited convenience and ease of use and maintenance as reasons for satisfaction with an intervention.[141, 142] Conversely, inconvenience and the time required to treat or filter water have been cited as reasons that households stopped using an intervention.[143, 144] Unfortunately, increasing convenience can be a challenge with respect to HWTS, as it does not address the issue of access to water but rather requires additional steps after collecting the water and bringing it home. Such additional steps can be barriers to achieving long-term behavior change.

2.2 Systematic Review of Literature Centered around HWTS RCTs

2.2.1 Methods

This literature review and analysis is centered on a set of articles on HWTS RCTs that was then built out to a larger collection of literature connected to these articles by citations. In focusing on this collection, I defined a sub-conversation on HWTS that I would explore to better understand knowledge creation and sharing and its effects on the conversation itself. In the following sections, I explain how I identified the original set of articles, generated the collection of literature around these articles, visualized the connections within this collection of literature and explored the discussion within this collection.

Identification of HWTS RCTs

In defining the system for analysis and mapping, I started with RCTs of HWTS interventions. Although there are known limitations to unblinded RCTs (as previously discussed), such studies are still currently the most well established and accepted means of evaluating health impact of HWTS in the field and are heavily relied upon and referred to by members of the HWTS sector when making decisions around production, implementation, funding and scale-up. For the purpose of this analysis, I focused on published articles, as this enabled me to track citations, establish connections, and explore the network generated by these connections.

To begin, I first established the list of peer-reviewed articles on HWTS RCTs. This set of articles comprised:

1. 22 articles corresponding to the HWTS RCTs analyzed by Hunter 2009 (which, in turn, was an updated list of those used by Schmidt and Cairncross 2009); and
2. 13 articles on HWTS RCTs published after Hunter 2009 up to June 2014. (Thus, I expanded the prior list by five years)

The data analyzed in Hunter 2009 included all but one of the studies used by Schmidt and Cairncross 2009[c] as well as further studies from 2007-2009 to bring the collection up to date at the time, using Web of Science (WoS) and Ovid Medline. In addition to these papers, Hunter used WoS to screen for other relevant papers among those that referred to prior systematic reviews or other reviews that he identified as being important. The steps of bringing the collection up to date and screening in WoS led to the addition of five more papers covering seven data sets. This led to a total of 39 data sets from RCTs on HWTS found in 27 separate studies (Hunter 2009).[145] For these 27 studies, I identified 23 published articles available, with the remainder being either unpublished data (DuPreez 2004, Garrett 2004) or dissertations (Austin 1993, Handzel 1998). Of the 23 articles, one (Universidad Rafael de Landivar) was published only in Spanish and was not used for this study.[d] The bibliographical information for the final list of 22 articles used from Hunter 2009 is presented in Appendices

[c] Hunter excluded the study because responses to Schmidt and Cairncross 2009 suggested that factors outside of the intervention resulted in the lack of effect found by the study. See Hunter 2009 for more information.
[d] See Hunter (2009) for further information.

Appendix A.

It is important to note that Hunter 2009 focused on the five "proven" HWTS methods, as set forth by the CDC and USAID.[146]And so, for the purpose of establishing a list of RCTs that updated the list from Hunter 2009, I also focused on these five HWTS options. To bring the list up-to-date to June 2014, I searched for articles on HWTS RCTs published after Hunter 2009 using the databases WoS and SCOPUS, with the latter being added as per the recommendation of Hunter (personal correspondence). Because the search terms used in Hunter 2009 were not made publicly available, I used the list of search terms from Fiebelkorn et al. 2012 as a starting point, but modified this list using wildcards to allow for different spellings and forms of words.[147] For example, instead of "flocculant-disinfectant," I used "floccul*-disinfect*" to allow for flocculent-disinfectant, flocculation-disinfection or flocculant-disinfectant. Further, I added the terms "household water treatment" and "*home water treatment"[e] based on preliminary searches without and with those terms. Finally, I removed "water boil," as boiling did not fit into the selection criteria, which are presented below. The finalized list of search terms and Boolean operators can be found in Table 5.

[e] The * here was intended to allow for possible phrases such as "in home water treatment" or "in-home water treatment" or simply "home water treatment," based on what I found in a quick review of how such a phrase is used in the literature.

Table 5. Search terms

"solar water disinfection" OR "solar disinfection" OR "solar disinfected water" OR "SODIS" OR "*home drinking water treatment" OR "floccul*-disinfect*" OR "point-of-use water" OR "free chlorine" OR "water chlorination" OR "hypochlorite disinfect*" OR "household drinking water" OR "safe water" OR "safe water system" OR "stored drinking water treatment" OR "untreated water" OR "household-level water disinfect*" OR "water treatment product" OR "water filt*" OR "ceramic filt*" OR "biosand filt*" OR "household water treatment" OR "*home water treatment"

The following selection criteria were applied to the search results:

1. Randomized, controlled trial.
2. Performed on one of the 5 “proven” HWTS options as designated by USAID/CDC: chlorine, flocculant-disinfectant, SODIS, ceramic filtration, biosand filtration.
3. Performed in a low- to medium-development country on the Human Development Index, as applied in Fiebelkorn et al. 2012.

In SCOPUS, the use of the search terms in the “Article Title, Abstract, Keywords” field for results from 2009-2014 and document type “Article” produced 6,291 results. I then searched within the results for “random* control* trial*” OR RCT, which produced 182 results. No duplicates were identified. The same selection criteria were applied to the title and abstract of the 182 articles, which led to the exclusion of 160 articles, leaving 22 articles. Full-text screening led to the exclusion of 7 more articles, with 15 remaining. Because Hunter 2009 captured some articles published in 2009, there was an overlap of 2 articles (Mausezahl et al. 2009 and Stauber et al. 2009), leading to 13 new articles. This process is represented in a PRISMA[f] flow diagram in

Figure 1 below. A similar search and inclusion/exclusion process was performed in WoS. The list of 11 new articles identified in WoS was a complete subset of the 13 from SCOPUS. The 13 new articles, which can be found in Appendix B, brought the final list of articles on HWTS RCTs to 35.

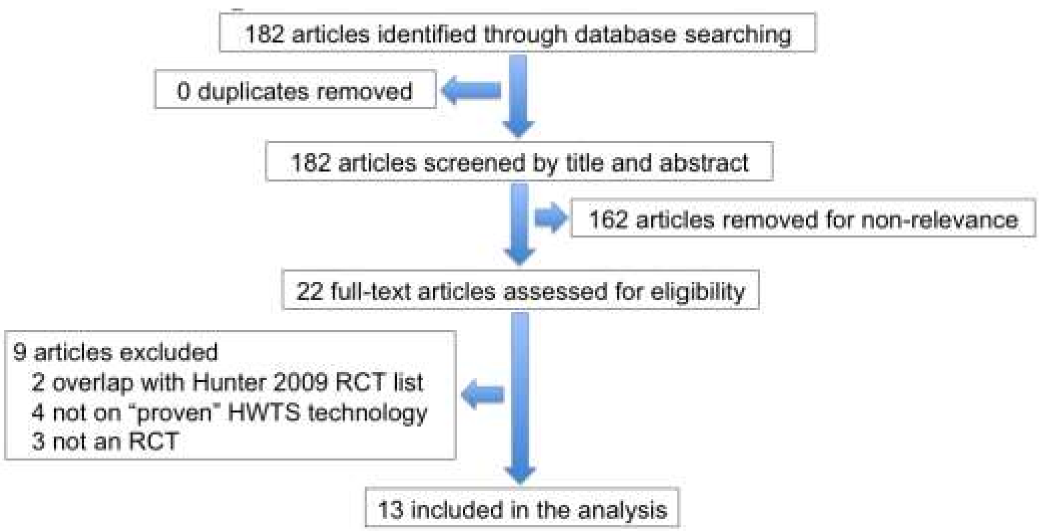

Figure 1. Flow diagram describing RCT article search and inclusion/exclusion process in SCOPUS

Generation of Collection of Literature

Having established an updated list of publications on HWTS RCTs, I then built up the collection of literature that is centered upon these publications: that is, the literature that is cited by the articles on RCTs ("Cited References") and the literature that cites the articles on RCTs ("Citing Articles"). Details on this process can be found in Appendix C.

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[f] "Preferred Reporting Items for Systematic reviews and Meta-Analyses": Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P., Clarke, M., Devereaux, P.J., Kleijnen, J. & Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *Annals of internal medicine*,*151*(4), W-65.

The total number of Citing Articles in this collection was 600, while the total number of Cited References was in the thousands. Of the Cited References, 2,536 were cited by at least two articles on RCTs and/or Citing Articles.

Textual Analysis

I performed a basic textual analysis of the titles and abstracts of the 35 articles on RCTs and their 600 Citing Articles. The intent of this simple analysis was to use the repository of titles and abstracts available in the exported files (see Appendix C) as an opportunity to explore basic trends in what HWTS options are being talked about and how they are being evaluated. By performing this analysis, the intent was to provide a more quantitative look at these trends than I would be able to give in a written summary of what I encountered and trends that I sensed emerging as I read all of the abstracts. The basics of this process can be found in Appendix C, and the results of this simple analysis are presented in a later section.

Visualization of Collection of Literature

I then worked with a collaborator[g] to create a user-friendly visualization of the body of literature. The basics of this process and examples of visualizations can be found in Appendix C as well, but due to challenges faced along the way, the user-friendly visualization was not completed. However, the user capabilities built into the trial version of the visualization – ordering by publication date, searching for author or keyword and highlighting connections – facilitated exploration of prominent publications and their

[g] Johns Hopkins University doctoral candidate Chris Kelley.

relationships with other publications in the collection, the results of which are presented in the latter half of this chapter. Screen shots taken from this visualization will also be used later to help the reader understand the relationships within the collection with regards to three highly cited papers.

2.2.2 Results and Discussion

As explained above, the textual analysis was performed on the titles and abstracts of the 35 articles on RCTs and their 600 Citing Articles. These publications span almost 30 years, from Kirchoff et al. in 1985, to when the search was performed in June 2014. In H) and health-related sectors.

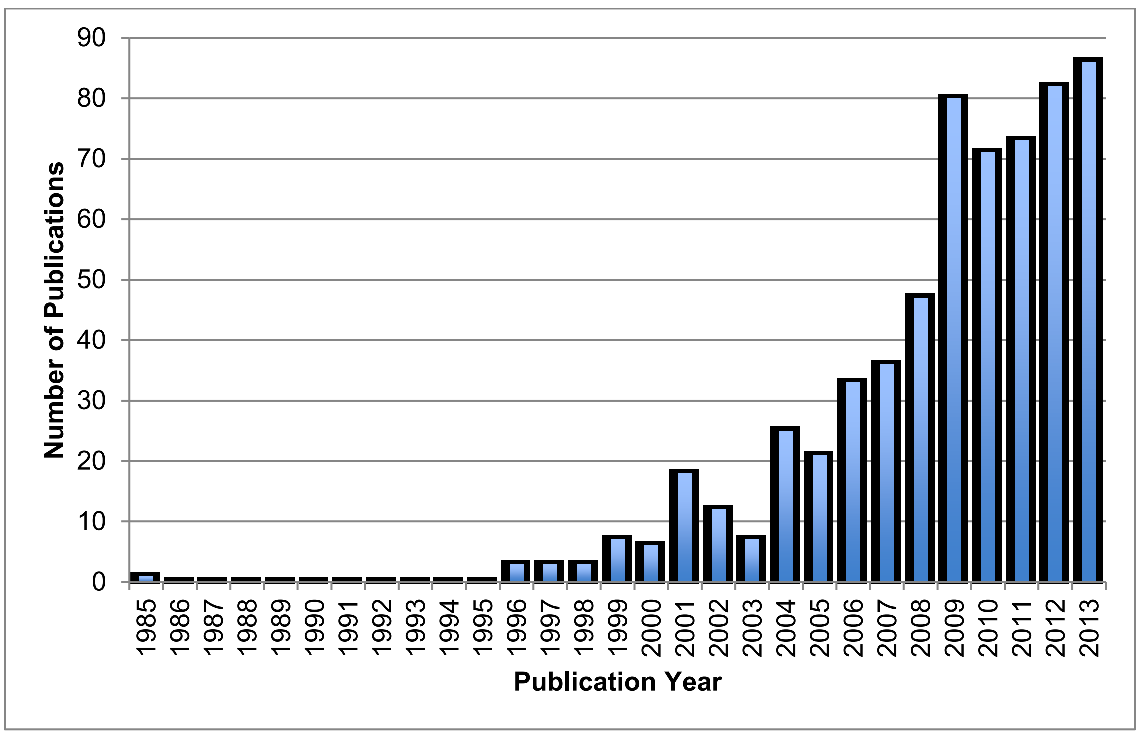

Figure 2 below, one can observe that, within this collection of publications, there has been a steady trend upward in the number of peer-reviewed articles on HWTS since

1996.[h] As such, this plot reflects what I have sensed as a member of the HWTS sector over the past half dozen years, which is not only increasing research activity around HWTS but also an increasing awareness of HWTS in other water, sanitation and hygiene (WASH) and health-related sectors.

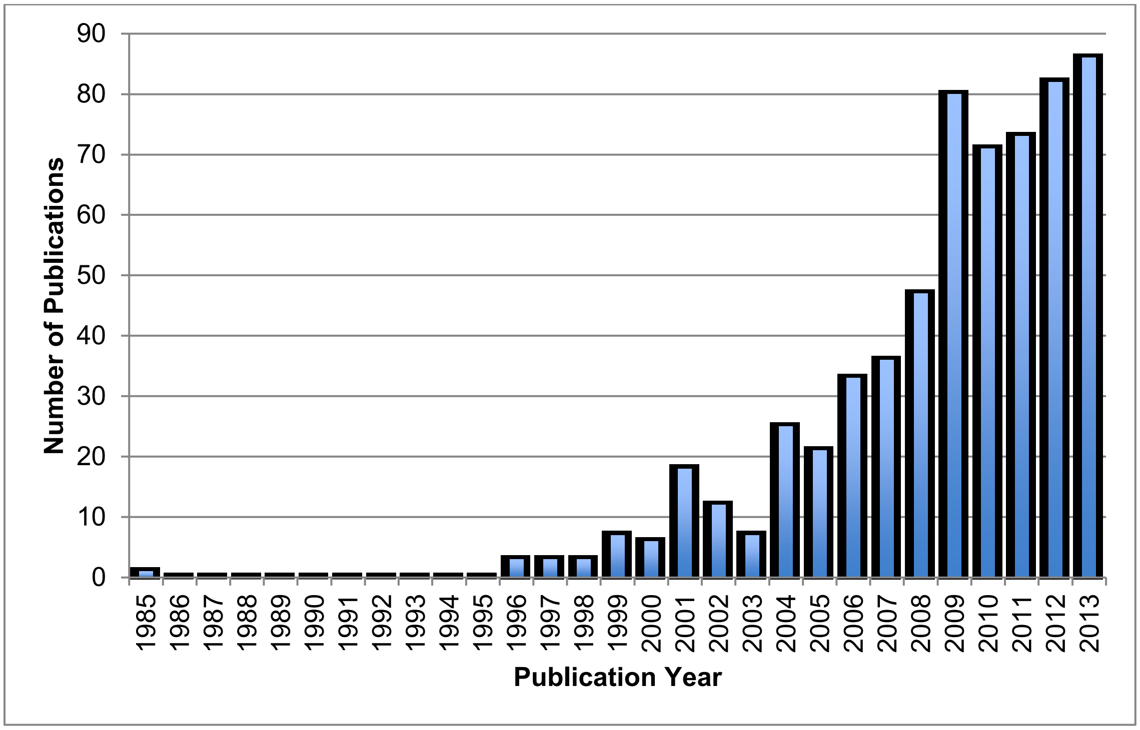

Figure 2. Number of RCTs and Citing Articles by Year

HWTS Options

[h] 2014 has been excluded from all plots in this section because only the first 5 months were captured in the June 2014 search.

As for what HWTS options were most talked about within this collection of literature, several unsurprising trends can be observed in

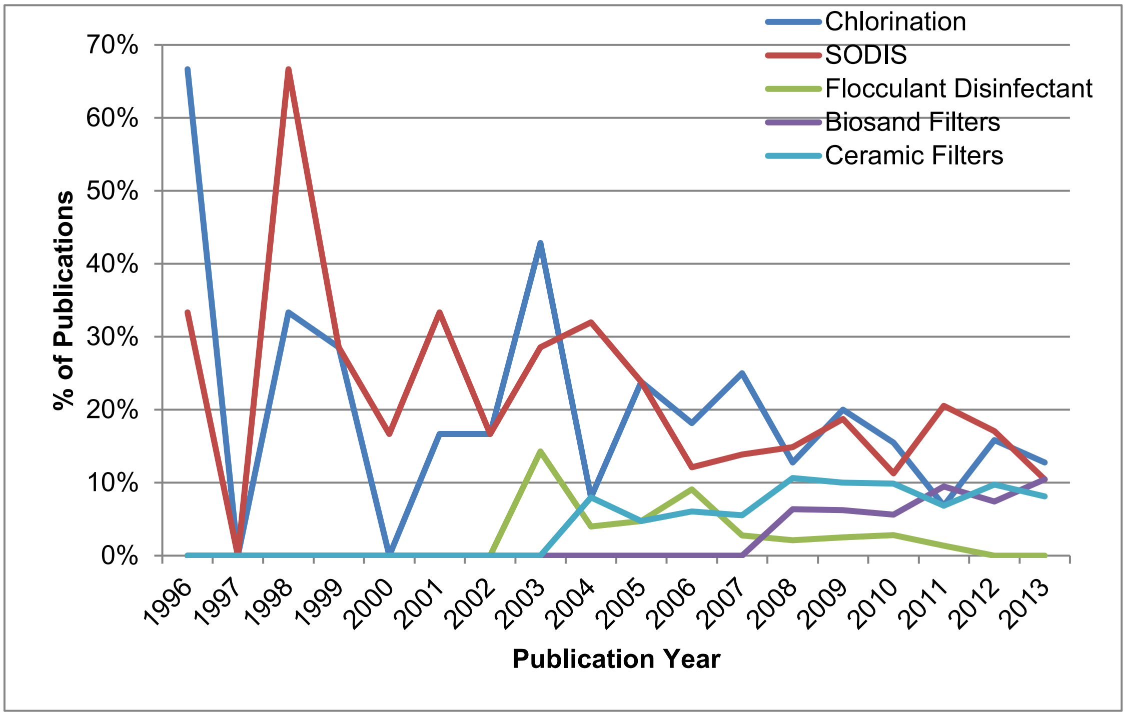

Figure 3 below. By percent of publications, chlorination and SODIS were the main focus of this literature until Procter and Gamble (P&G) Purifier of Water (flocculant-disinfectant) came on the scene, followed shortly thereafter by ceramic filters, with biosand filters entering the conversation in the scientific literature last. There is, of course, a delay in trends showing up in the scientific literature due to the time it takes to write up one's research findings as an article, submit the article for review, revise if necessary, and submit for publication, or restart the process with another journal if rejected. This delay can be seen, for example, by looking at P&G Purifier of Water, which shows up in this collection in 2003, 3 years after the launch of the product.[148] As a result of the time lag, this collection of articles is not the most up to date indication of what research is being carried out. It does, however, effectively represent the formal conversation around HWTS, which in turn influences what is being talked about at conferences and what is being considered as next steps for research, based on the findings of others.

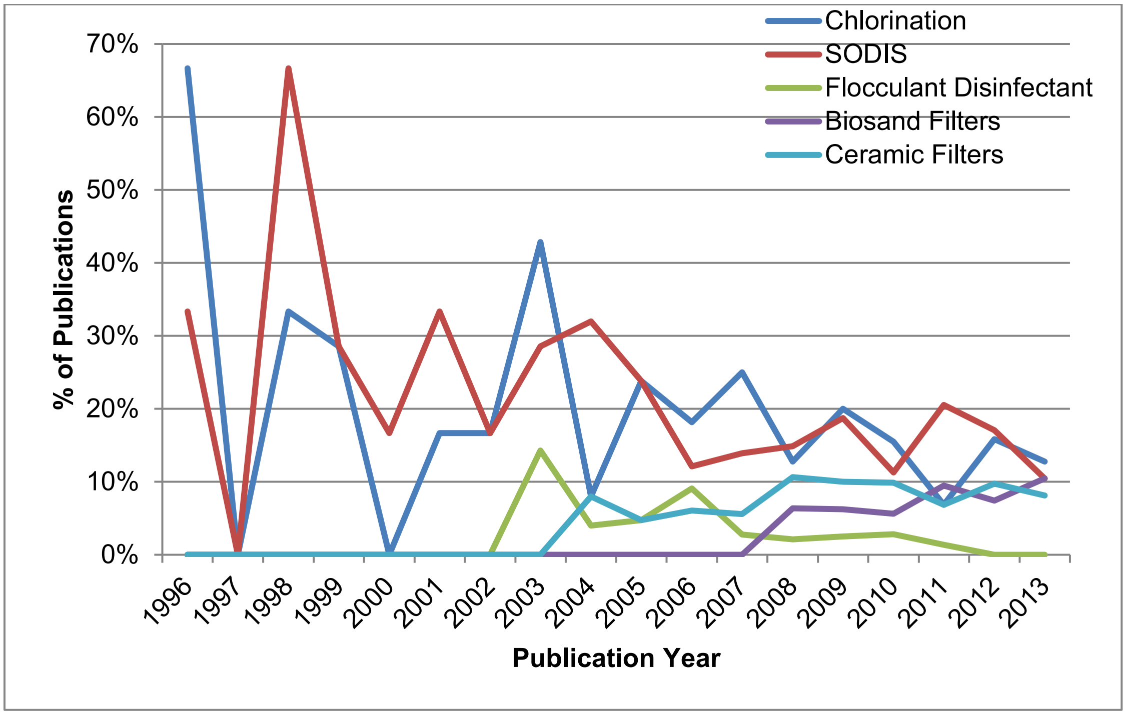

Figure 3. Percent of Publications, by Proven HWTS Option

Assuming all articles must go through a similar review and publication process with a similar timeline, the conversations around the 5 HWTS options experienced a similar time lag, so they can be compared and contrasted. As seen in

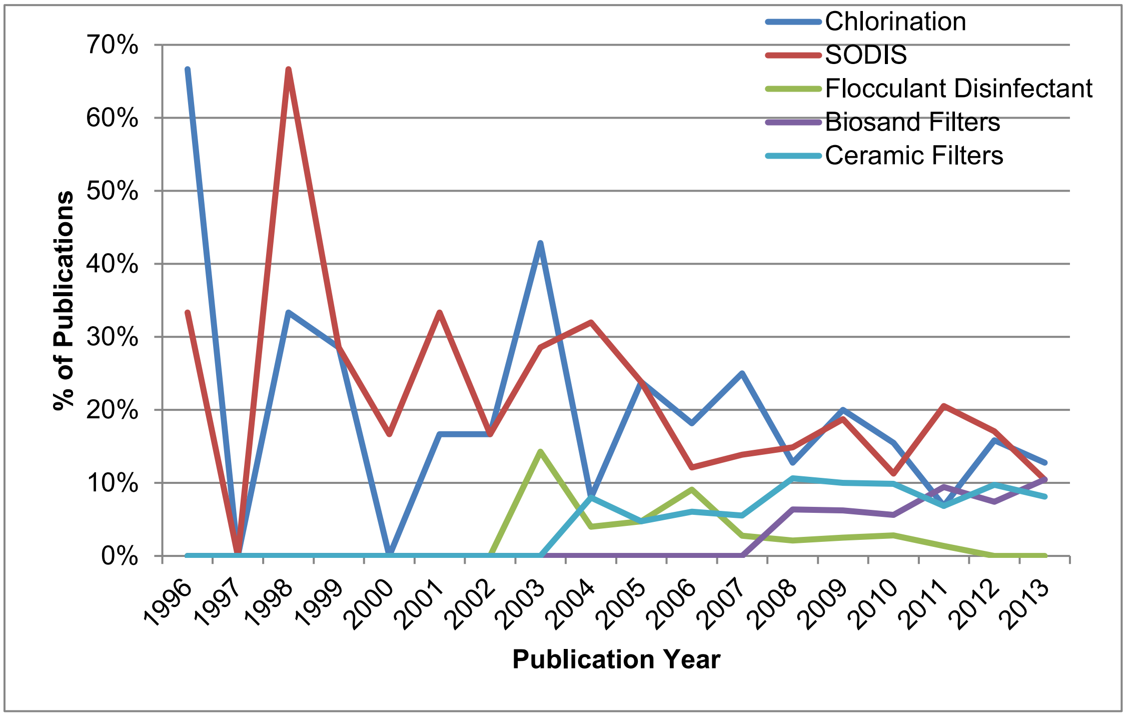

Figure 3, although chlorination and SODIS remain the most talked about of the 5 options, their prominence has decreased over the past two decades. One can observe that P&G Purifier of Water was a topic of discussion in about 10% of publications for several years but then gradually disappeared from the conversation over the next half dozen years. Ceramic filters are covered in about 10% of publications from the collection, starting in 2004 and continuing to the present. The attention paid to biosand filters has gradually increased to about 10%, comparable to ceramic filters and, at this point, to chlorination and SODIS.

This evening out of attention amongst the 5 established options is promising, indicating a well-rounded conversation that considers multiple options as opposed to focusing on one solution. But what of other HWTS options? In

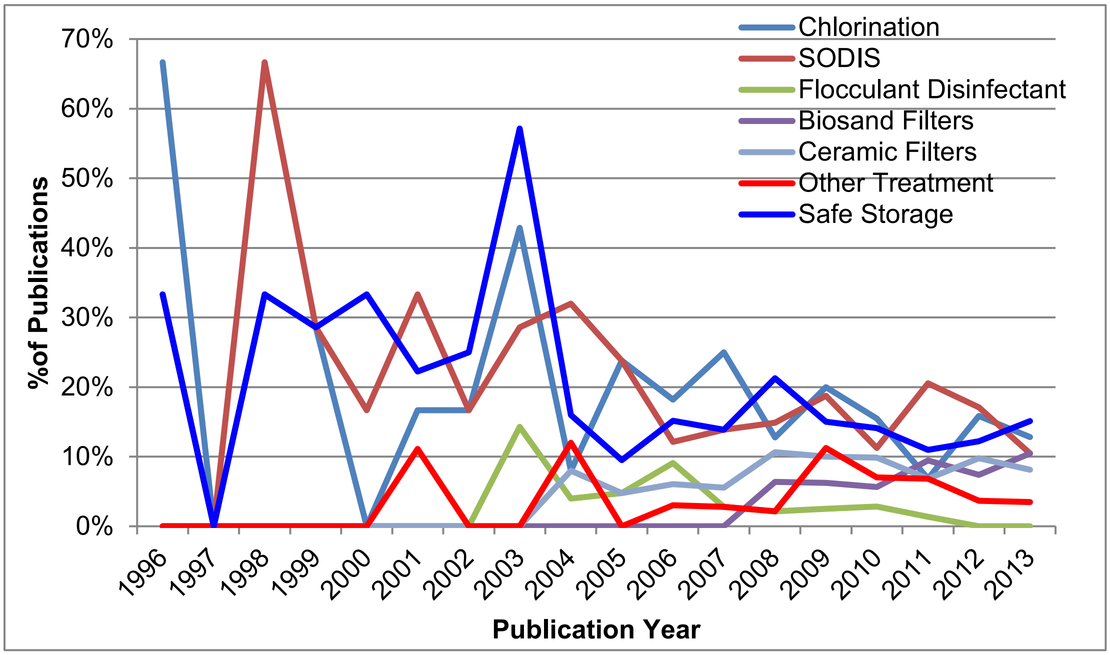

Figure 4, I present the percent of publications within the collection that discussed safe storage and the percent that discussed other treatment options, with the 5 proven options in the background for reference. Here, other treatment options included membrane filtration, flocculation by alum or moringa seeds, filtration using a sari cloth, or even simple settling. These other treatment options show up, but even when all combined, are not discussed as much as the 5 options.

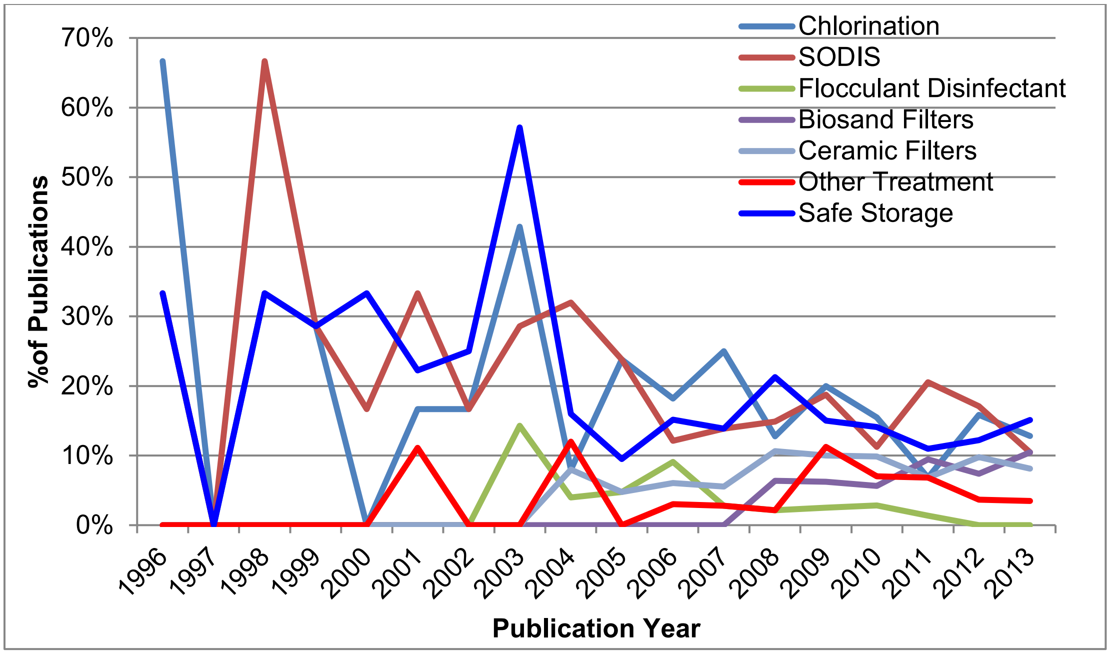

Figure 4. Percent of Publications, by HWTS Option, including Safe Storage and Other Treatment

With respect to safe storage, one can observe in this plot that it has been a dominant topic over the past couple of decades but that discussion on this element of HWTS has decreased over time. While it makes sense for a given HWTS option's share of publications to go down as more options enter the sector, safe storage is an important element for all HWTS options and has a significant impact itself on effectiveness and public health impact. One possible reason for this decrease is the decrease in the proportion of articles that discuss chlorination, as safe storage is a critical element of the CDC's Safe Water System and would therefore be mentioned in many articles on chlorination. Outside of that, though, a decreasing emphasis on safe storage would be cause for concern and is something that should be explored further, both in the literature and in practice.

Evaluation Criteria

Regardless of which HWTS option was being considered, what was actually being discussed – performance in the lab or in the field, decrease in diarrheal disease, challenges around correct, consistent, continued use? As I did with the different HWTS options, I also performed a basic analysis of the words used in the conversation around HWTS in the scientific literature. Specifically, I created word groups for the four categories of evaluation established earlier: efficacy, effectiveness, public health, and behavior change.

As with the analysis with respect to the 5 HWTS options, there were no real surprises. In

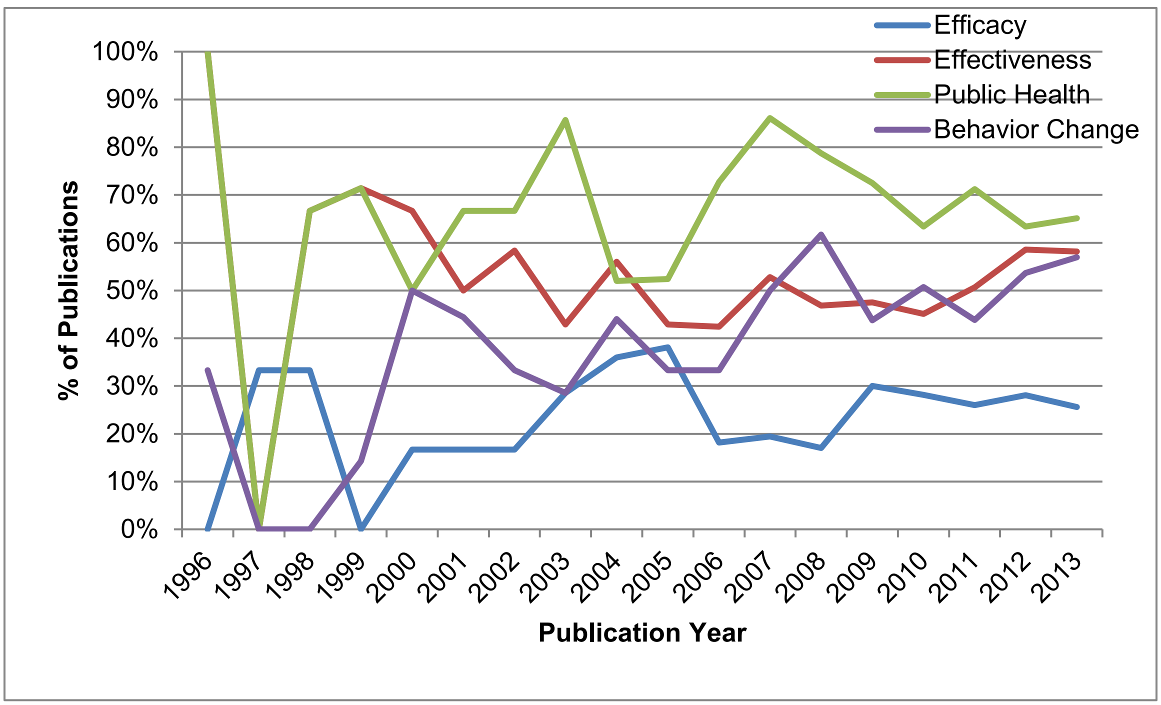

Figure 5, we can see that discussion around efficacy and effectiveness has remained relatively constant over time, with more articles discussing effectiveness than efficacy throughout. Discussion around public health impact has been more volatile, but for the most part, this means of evaluating HWTS has received the most attention.

Finally, discussion around behavior change, which included terms such as uptake, reported use, compliance, and acceptable, has been trending upward over the period of interest and is now discussed as often as effectiveness and more often than efficacy, indicating an increasing realization of and emphasis on the importance of behavior change issues for success.

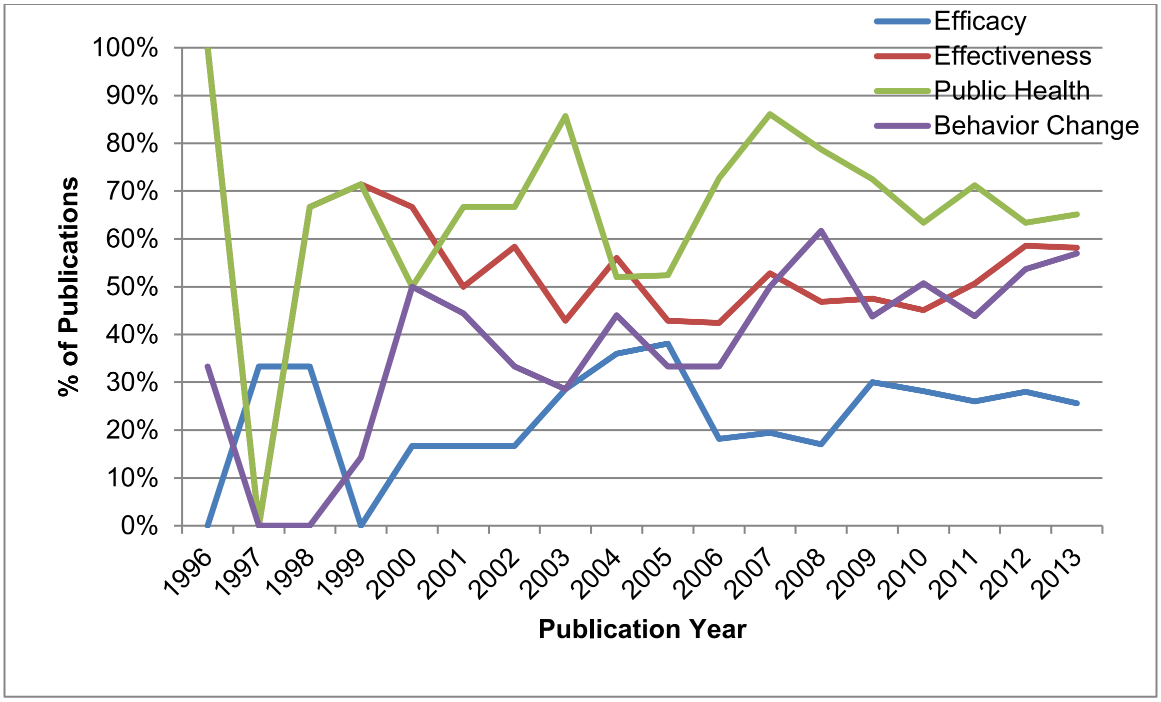

Figure 5. Percent of Publications, by Evaluation Criterion

Limitations

As established in the methods, this textual analysis was a very simple process that was intended to provide insight into trends in the collection of literature but not to paint a precise, detailed picture. As such, there were a couple of limitations to this analysis that kept it from achieving more. First, because this collection of literature was built around articles on RCTs on the 5 proven HWTS options and not on more recently developed HWTS options like membrane filters (e.g. the Sawyer Filter, LifeStraw Family, LIFESAVER cube), it is possible that these emerging technologies are dominating the conversation but are not captured here. Second, the word groups were created from several passes through the complete word count list, which presented individual words or hyphenated words, and the resulting list was of similar content for the most part, although I added some potential combinations (e.g. slow sand filter, Safe Water System). As such, it is likely that some word combinations were missed. For example, one study on the P&G Purifier of Water described it as “a product incorporating precipitation, coagulation, flocculation, and chlorination technology (combined product);” this publication would have been counted for chlorination but not for flocculant-disinfectant.[149] Further textual analysis would benefit from a closer inspection of abstracts for such instances as well as the use of Boolean operators to capture more potential word combinations.

A second limitation also emerges in the above example that complicated counting instances for P&G Purifier of Water and would have similarly complicated counting, for example, LifeStraw Family instances. This limitation is that product names are rarely, if ever, present in the title or abstract of an article, requiring that the reader search for the product name in the article body, which often is not readily or freely available. For this and many other reasons, a much richer analysis with more detailed insights would result from a textual analysis of the complete articles.

2.3 Impact Evaluation and Citation Analysis of Most Cited Literature

2.3.1 Most Cited Literature

Within the established collection of literature around the 35 articles on RCTs, I identified the most cited RCT publication (Quick et al. 1999) and the most cited Cited

Reference (Sobsey 2002).[i] For Quick et al. 1999, this count (113) was the same as the times cited in SCOPUS, because of how the collection was generated. Sobsey 2002 was cited by 76 publications in the collection of literature.

Sobsey 2002 qualifies as grey literature and, in particular, grey literature of interest in this study, thereby providing a unique opportunity to explore the citations of a grey literature publication. But because Sobsey 2002 is grey literature, it was more difficult to count times cited using a database such as SCOPUS or WoS, which are not designed for tracking grey literature. Nonetheless, I was able to track down Sobsey 2002 and its Citing Articles in WoS to a certain extent. For consistency, I therefore also relied on WoS and not SCOPUS for tracking all other citations. WoS identified 86 instances of Sobsey 2002 being cited, 82 of which were articles; this times cited list is known not to be complete, however, as evidenced by my discovery of a publication (Peter-Varbanets et al. 2009) that cited Sobsey 2002 but was not in the WoS times cited list.[150] For the purpose of this study, I will be using the 82 articles identified as Citing Articles by WoS.

The most cited systematic review and meta-analyses on HWTS interventions was Fewtrell et al. 2005. Because of challenges establishing all of the connections between RCTs and Citing Articles within the collection of literature, I relied on times cited in WoS to identify Fewtrell et al. 2005 as the most cited systematic review and meta-analysis and also to identify its Citing Articles.

2.3.2 Methods

[i] Based on times cited within this collection, not in WoS or SCOPUS.

For each of these three publications, I used WoS to track citations backward to find the context of the citation within the citing reference. For this identification and analysis, I included only articles (as specified by WoS) and not other document types, such as books or conference proceedings, for which finding and reading the material would be excessively time consuming and often not productive. For Quick et al. 1999 and Sobsey 2002, I examined the published text of all Citing Articles (96 and 82 Citing Articles, respectively); for Fewtrell et al. 2005, however, I only followed the 100 most highly cited Citing Articles (out of the total of 440 Citing Articles) for reasons of time.

Examination of Citing Article texts involved a manual use of WoS for each of the three publications to obtain the list of Citing Articles. For each Citing Article, I found and accessed the article and then searched the article for the instance(s) of reference to the publication of interest. For each instance, I summarized its focus in the form of a short phrase and documented this, as well as the bibliographic information, in a spreadsheet. After tracking all of the citations, I then did a second round of coding, in which I grouped the different phrases into common themes, such as Boiling, Effectiveness of HWTS, Publication Bias, Comparing HWTS to Others, and Interim Solution. This coding was more straightforward for some citations than others – not all Citing Articles applied to HWTS, as many were on WASH more broadly and not specifically HWTS. There was extensive overlap of code groups between the three publications, but they were not identical. In the table below, I present several examples of how Sobsey 2002 was cited and how I then coded that citation.

Table 6. Sobsey 2002 Example Citations and Codes

Citing Reference	Citation of Sobsey 2002	Focus of Citation
Clasen et al. 2008	"Boiling or heating with fuel is perhaps the oldest means of disinfecting water at the household level."	Boiling
Jain et al. 2010	"The definitive response to this problem would be the universal provision of piped, treated water, but because of insufficient resources, achievement of this goal remains remote. For this reason, a number of household water treatment technologies have been developed, tested, and disseminated to protect the health of populations lacking access to safe water."	Interim solution
Onda et al. 2012	"Additionally, water that must be transported manually from the source to the home, and any water stored in the home, as is common with other improved sources, can become contaminated due to unsanitary storage conditions."	(Re)contamination

For each of the three most cited publications identified above, I will first discuss their connections to the collection of literature built around the 35 RCTs. I will then discuss the publication's focus and key findings, followed by the focus topics of its Citing Articles as well as the coded content of the citation instances with respect to the publication of interest. In comparing and contrasting among the different publications, I consider how the focus of the Citing Article relates to that of the cited publication and the reason and manner of the citation. In this way, I am able to explore how the different types of publications are used and how they contribute to the ongoing discussion around HWTS in the literature.

2.3.3 Results and Discussion

RCT: Quick et al. 1999

Of the 35 articles on HWTS RCTs that were identified for this analysis, Quick et al. 1999, which evaluated the CDC's Safe Water System (SWS), was the most cited: 105 citations in WoS (113 citations in SCOPUS) as of June 2014. The times cited in WoS for this and the other 34 RCT publications can be found in Table 7 below.

Table 7. HWTS RCTs and Times Cited in Web of Science, Ranked by Times Cited

Year	Authors	Times Cited	Year	Authors	Times Cited
1999	Quick et al.	105	2004	Luby et al.	27
1996	Conroy et al.	94	2006	Doocy and Burnham	25
1998	Semenza et al.	92	2006	Clasen, Brown, Collin	22
2002	Quick et al.	89	2009	Tiwari et al.	22
1999	Conroy et al.	69	2010	Du Preez, McGuigan, Conroy	20
2003	Reller et al.	57	2011	McGuigan, Samaiyar, Du Preez, Conroy	15
2005	Crump et al.	54	2008	du Preez et al.	12
2005	Lule et al.	54	2011	du Preez et al.	12
2006	Rose et al.	50	2010	Jain et al.	10
2003	Sobsey, Handzel, Venczel	49	2010	Firth al.	8
2004	Clasen, Brown, Suntura, Cairncross	47	2012	Stauber et al.	8
2006	Luby, Agboatwalla,Painter	45	2012	Luoto et al.	4
1985	Kirchhoff et al.	36	2011	Luoto et al.	3
2009	Stauber et al.	35	2013	Boisson et al.	3
2005	Clasen et al.	34	2012	Stauber et al.	2
2009	Mausezahl et al.	31	2012	Fabiszewski de Aceituno et al.	0
2008	Brown, Sobsey, Loomis	30	2013	Mengistie, Berhane, Worku	0
2006	Chiller et al.	28			

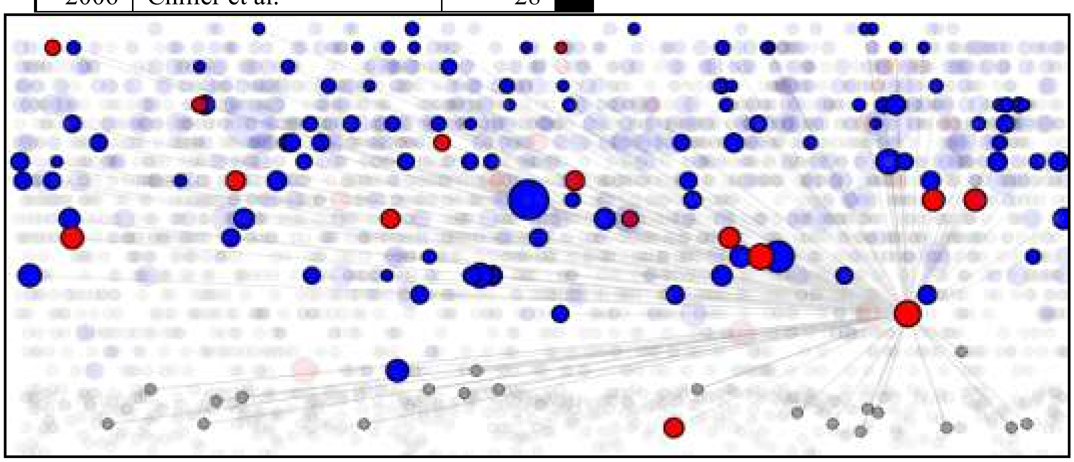

Figure 6 is a visualization of the citation network for Quick et al. 1999. In this figure and in all subsequent visualizations, the red nodes are articles on RCTs, the blue nodes are Citing Articles, and the grey nodes are Cited References. The size of the red RCT nodes and blue Citing Article nodes is scaled according to Times Cited in SCOPUS. The size of the grey Cited References is set, not scaled, as we did not have information on Times Cited for these publications. The publications are organized on the vertical axis according to publication year, with the oldest publications at the bottom and the newest at the top. The horizontal distance between nodes does not have any significance.

The publications not connected to Quick et al. 1999 as a Citing Article or Cited Reference are faded out. As a result, all of the nodes that are clearly seen and colored are connected to Quick et al. 1999 either as a Cited Reference (below Quick et al. 1999 in the visualization) or a Citing Article (above). Quick et al. 1999 is the red node in the bottom right corner from which all of the connections radiate. All 113 SCOPUS Citing Articles of Quick et al. 1999 are shown in this visualization, with a relatively even distribution over the 15 years since its publication. One can quickly observe that a number of the RCTs on HWTS published afterward – 13 of 30, or 43% – cited the publication, while Quick et al. cited 1 of 3 prior RCTs (with Conroy et al. 1999 published the same year).

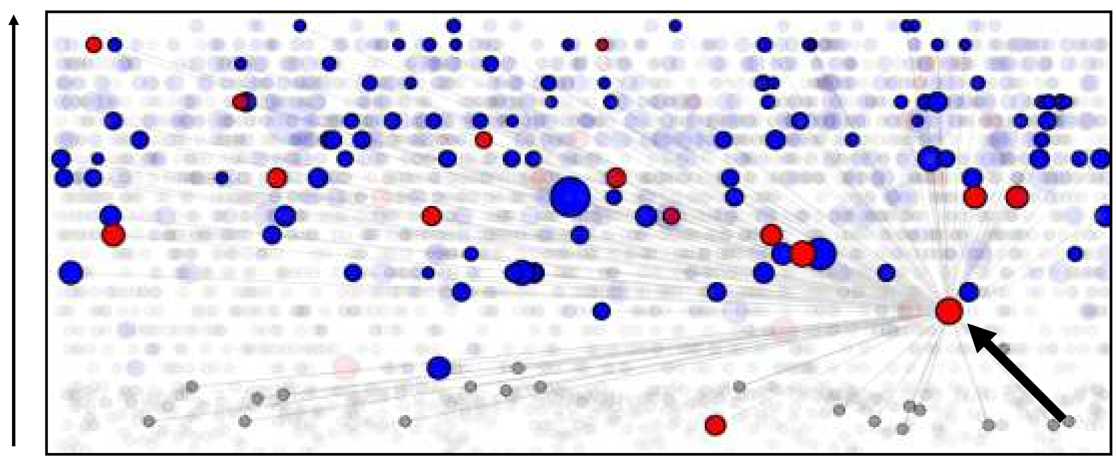

Figure 6. Most cited RCT publication: Quick et al. 1999 (cropped visualization)

The key findings of Quick et al. 1999 were that households receiving the SWS reported fewer episodes of diarrhea than control households, and their stored water was less contaminated with E. coli than control households. Although not highlighted in the abstract, Quick et al. 1999 also measured the reported and observed use of the intervention (disinfection and safe storage) over the duration of the study.

For Quick et al. 1999, WoS identified 96 Citing Articles.[j] Of these, 56 (58%) focused on HWTS interventions. Of these articles on HWTS, 25 were on household chlorination of drinking water, which was the focus of Quick et al. 1999, with the remaining 31 focusing on other HWTS interventions, including boiling, filtration, ceramic pot filters and flocculant-disinfectant. As for the articles not focused on HWTS interventions, 18 presented results on other WASH interventions, such as hand-washing, sanitation, WASH in schools, and rainwater harvesting; 10 focused on behavior change as it related to WASH; and 7 focused on diarrheal risk factors.

With respect to the content of the references to Quick et al. 1999 in these 96 Citing Articles, 64 (67%) cited the key findings as presented above, with many more focusing on the intervention's impact on diarrheal disease (62) than on its impact on stored water quality (11). A smaller number of articles (4) cited Quick et al. 1999 regarding the adoption of the intervention. The next area that received the greatest amount of focus when referencing Quick et al. 1999 was the issue of contamination after collection (or recontamination after treatment) and the need for and importance of safe storage (11 of 96). This was followed by an emphasis on the inexpensive nature of HWTS as a solution (7 of 96).

In addition to the low-cost nature of the SWS intervention, Quick et al. pointed out a number of other strengths of HWTS in the article's discussion section: "While supplying piped, treated water to all households remains elusive for many communities,

[j] Of the 105 citations identified by WoS, 96 were articles, which were the focus of this analysis.

this point-of-use disinfection and safe water storage intervention can be rapidly disseminated, is inexpensive, simple to use, and adaptable to a variety of conditions."[151] References to these endorsements showed up in 6 of the 96 Citing Articles when supporting HWTS – as an interim solution; as an appropriate, acceptable and/or practical approach; or as an established option. With another 2 articles discussing the range of options available for HWTS, 15 of the 96 Citing Articles referred to discussion points from Quick et al. 1999, as opposed to results.

Systematic Review and Meta-analysis: Fewtrell et al. 2005

In June 2014, I identified 10 systematic reviews and meta-analyses that included HWTS interventions in their review and analysis; some focused exclusively on HWTS interventions, whereas others included other WASH interventions. These 10 publications were also found in the collection of literature established around the 35 articles on HWTS RCTs. They are presented in Table 8 below, ranked according to times cited in WoS (as of December 2015). Of these systematic reviews and meta-analyses, Fewtrell et al. 2005 was cited the most in the WoS collection: 440 times.

Table 8. Systematic Reviews and Meta-Analyses on HWTS and Times Cited in Web of Science

Year Published	Authors	Title	Times Cited
2005	Fewtrell et al.	Water, sanitation, and hygiene interventions to reduce diarrhoea in less developed countries: a systematic review and meta-analysis	440
2007	Clasen et al.	Interventions to improve water quality for preventing diarrhoea: systematic review and meta-analysis	179
2010	Cairncross et al.	Water, sanitation and hygiene for the prevention of diarrhoea	114
2009	Schmidt, Cairncross	Household water treatment in poor populations: Is there enough evidence for scaling up now?	112
2007	Arnold, Colford	Treating water with chlorine at point-of-use to improve water quality and reduce child diarrhea in developing countries: a systematic review and meta-analysis	111
2009	Hunter	Household water treatment in developing countries: comparing different intervention types using meta-regression	85
2009	Waddington, Snilstveit	Effectiveness and sustainability of water, sanitation, and hygiene interventions in combating diarrhoea	42
2012	Fieblekorn et al.	Systematic review of behavior change research on point-of-use water treatment interventions in countries categorized as low- to medium-development on the human development index	10
2013	Peletz et al.	Water, sanitation, and hygiene interventions to improve health among people living with HIV/AIDS: a systematic review	6
2014	Loevinsohn et al.	The cost of a knowledge silo: a systematic re-review of water, sanitation and hygiene interventions	0

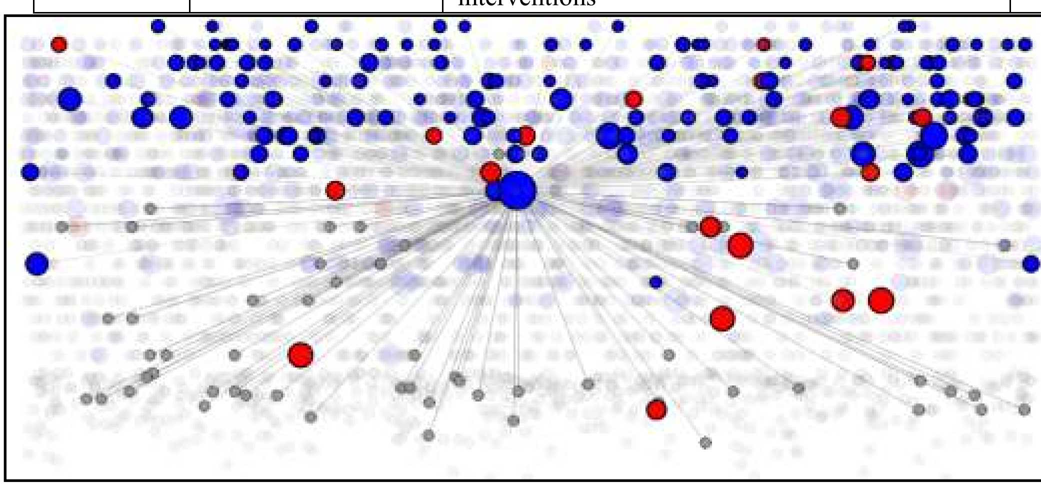

Figure 7 is the time-ordered citation network for Fewtrell et al. 2005 (large, blue node in the center of the visualization), which included in its review and analysis 7 of the 8 articles on RCTs in the collection that were published before the cutoff date of June 26, 2003 (Conroy et. al 1999 was not included). This is confirmed in the visualization, where you can see that Fewtrell et al. cites 7 articles on RCTs (as well as a few Citing Articles); in turn, it is cited by 13 of the 22 (59%) articles on RCTs published after 2005. Further, it is highly cited by the Citing Articles within the collection – a very influential publication.

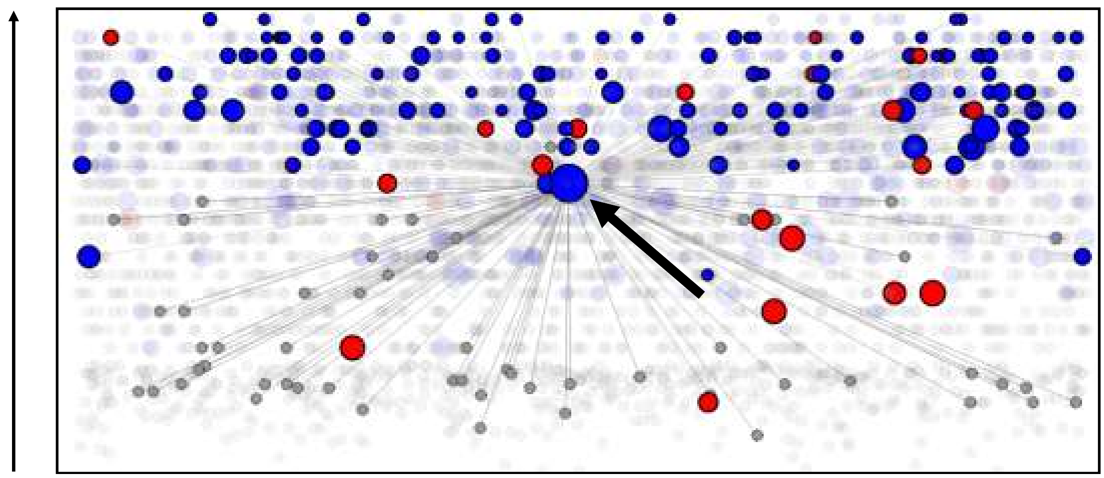

Figure 7. Most cited systematic review and meta-analysis: Fewtrell et al. 2005 (cropped visualization)

Fewtrell et al. 2005 provided summary estimates of the effectiveness of WASH interventions and found that all interventions significantly reduced the risks of diarrheal disease. These findings largely agreed with those of previous reviews, except water quality interventions at the point of use (i.e. HWTS) were found to be more effective than previously thought, and multiple interventions – combining, for example, a water supply intervention with a sanitation intervention – were not found to be more effective than standalone interventions. Fewtrell et al. 2005 also discussed the issue of contamination of water during transport and storage, highlighting the impact of HWTS and saying, “The result suggests that a water quality intervention at the point of use should be considered for any water supply programme that does not provide 24 h access to a safe source of water."[152] They noted, however, that many of the studies identified for review and analysis (12 of 38, or 32%) were either "poorly done or poorly reported," and suggested the possibility of publication bias in the studies on HWTS, indicating the need to improve on these aspects to increase the reliability and utility of published findings.[153]

As mentioned previously, tracking the citations in the 440 publications that cited Fewtrell et al. 2005 would have been time prohibitive. After ranking the Citing Articles in WoS according to times cited, I then followed the citations for the top 100 most cited. This number of articles was comparable to those investigated for Quick et al. 1999 (96) and Sobsey 2002 (82). Of these 100 Citing Articles, 33 were primarily focused on HWTS. The other key topics of focus were other WASH interventions (41), enteric diseases (14), and behavior change (8). Given that Fewtrell et al. 2005 evaluated WASH interventions and not just HWTS, this split does not go against expectations.

Within the 100 Citing Articles that were tracked, a comparable number of citation instances focused on HWTS interventions (51) and non-HWTS WASH interventions (60).[k] Focusing on the HWTS-related citation instances, a majority referred to Fewtrell et al.'s findings on the public health impact of HWTS interventions (31), and others (9) compared the findings on the impact of HWTS compared to that of other WASH interventions. These citations were focused on the key findings of the systematic review and meta-analysis that were presented in the publication's abstract. The other citation instances focused on the effectiveness of HWTS (6), put forth HWTS as a potential solution to the lack of access to safe drinking water (3), or provided a range of HWTS

[k] Some publications cited Fewtrell et al. 2005 in multiple instances.

interventions to consider (2). All of these instances of citing Fewtrell et al. 2005 when discussing HWTS were positive, in support of HWTS.

A much smaller number of citation instances (9) touched on the discussion points of Fewtrell et al. 2005 rather than on the findings of the meta-analysis on the impact of HWTS and other WASH interventions (111). As mentioned above, Fewtrell et al. was cited in 3 instances in which authors suggested HWTS as a potential solution to the lack of access to safe drinking water and twice when discussing the range of HWTS options that are available. In these instances, Fewtrell et al. 2005 was cited in support of HWTS. The other discussion points from Fewtrell et al. that citations touched on were the quality and availability of evidence (2), study limitations (1) and publication bias (1).

The reliance of the majority of citations on the results of the meta-analysis as opposed to the discussion points following the review and analysis indicates that this publication most advanced the field of research on HWTS (and WASH more broadly) through its analysis and the presentation of summary effect measures. These findings were used in support of specific WASH interventions and as a means of comparing and contrasting the impact of different interventions. HWTS was a prominent focus of the citation instances, which used the findings of Fewtrell et al. 2005 to bolster HWTS and its potential impact on public health as a solution to the lack of access to safe drinking water.

Grey Literature: Sobsey 2002

Of the approximately 2,500 Cited References that were cited by at least 2 publications in the collection, the most cited was a 2002 report written by Dr. Mark

Sobsey for the WHO entitled *Managing water in the home: Accelerated health gains from improved water supply*. This report was cited by 76 publications in the collection; these citations are shown in the time-ordered visualization seen in Figure 8 below. One can observe that 6 RCTs – of the 29 published after 2002 – cited this publication. WoS identified 82 articles as having cited Sobsey 2002. Because Sobsey 2002 was a Cited Reference (and grey literature), we did not collect information on its Cited References, which is why the visualization only shows connections moving forward in time. To provide some perspective as to the significance of Sobsey 2002 as a cited reference in the collection, less than 40% of the 2,536 Cited References that were cited at least twice in the collection were cited by 3 or more publications in the collection, 15% by 5 or more, and 3% by 10 or more, compared to the 76 Citing Articles for this publication.

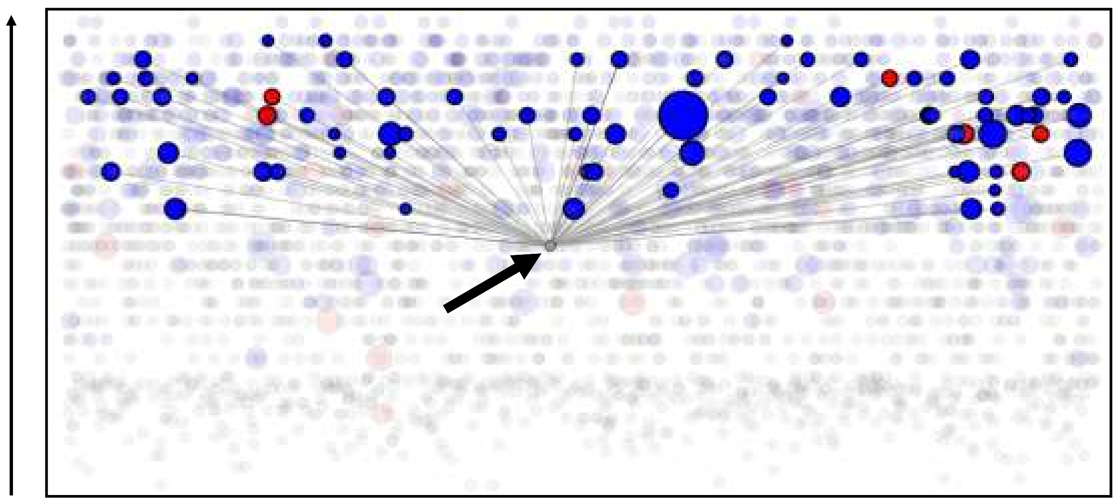

Figure 8. Most cited Cited Reference: Sobsey, 2002 (cropped visualization)

As to the intent of Sobsey 2002, Jamie Bartram, of the WHO at the time, expressed hope in the foreword that this document would provide "a scientifically sound and supportable basis for identifying, accepting and promoting" HWTS (Sobsey 2002, p.2).[154] Toward this end, Sobsey reviewed the currently available HWTS technologies according to the evidence available on their performance using the following criteria:

- Microbial effectiveness – both improving and maintaining water quality
- Reduction of diarrheal disease
- Ease of use
- Cost
- Accessibility
- Acceptability
- Sustainability
- Dissemination potential

Based on these criteria, Sobsey identified technologies that were the most widespread and had the greatest potential, with an emphasis on evidence from independent testing. These "most promising and accessible" technologies were:

- Boiling
- Solar disinfection (SODIS)
- Solar pasteurization
- UV radiation with lamps
- Ceramic filters
- Chlorination and safe storage (SWS)
- Combined systems consisting of chemical coagulation-flocculation, sedimentation, filtration, and chlorination

Although he found that none of the identified treatment technologies had been tested in combination, he connected back to standard practice in water treatment and its reliance on two or more technologies to act as multiple barriers to contamination of drinking water. In emphasizing the multiple barrier approach and its potential for application in household water treatment, Sobsey focused in particular on the use of filtration as pre-treatment before disinfection in order to remove turbidity.

Sobsey placed great importance on independent testing in his pursuit of information on different technologies. Although there was evidence available for the technologies listed above with respect to microbial efficacy, Sobsey noted the lack of documentation of effectiveness – that is, performance in the field. Further, he found that, except for the SWS and SODIS, the technologies had not been studied for diarrheal disease reduction; he concluded that epidemiological studies were an essential next step. Sobsey also looked at other metrics of performance that are more difficult to measure, such as community acceptance and cost recovery, finding that there was a great need for behavioral, motivational, and economic support for technology implementation.

In exploring the citation instances for Sobsey 2002, I found that statements made by Jamie Bartram in the foreword were just as significant to the literature that came afterward as points made by Sobsey himself in the actual document. Specifically, Bartram stressed the opportunity to use HWTS as an "interim" approach that could be implemented "quickly" to meet the need for safe water, as opposed to the "inappropriate response" he identified as waiting for piped, safe water systems at the community level.[155] He concluded:

> "Effective measures are needed immediately to provide at risk populations with safer water at the household level until the long-term goal of providing safe, piped, community water supplies can be achieved. There is now conclusive evidence that simple, acceptable, low-cost interventions at the household and community level are capable of dramatically improving the microbial quality of household stored water and reducing the risks of diarrheal disease and death in populations of all ages in the developed and developing world."[156]

This was a resounding endorsement of HWTS, and one that is echoed in many citation instances. But before going further into the content of the Sobsey 2002 citation instances, let us first look at the broader focus of the Citing Articles.

Of the 82 citing articles, 61 (74%) focused on HWTS, with the majority focusing on specific interventions and only 4 on HWTS more broadly. The different interventions and the number of articles of which they were a focus are presented in Table 9 below. Overall, 35 articles (43%) focused on filters and 24 (29%) on disinfection, with the three remaining articles focusing on other types of HWTS. Some articles focused on more than one intervention, but only two in the sense of combining filtration and disinfection as a multiple barrier approach.[157,158] In this sense, Sobsey's emphasis on employing multiple barriers for treatment at the household level did not contribute to more interventions and investigations on this approach. As for non-HWTS topics that some articles focused on, those receiving the most attention were water quality (7), behavior change (5), and other water interventions (4).

Table 9. Topic focus of HWTS-focused Sobsey 2002 citing articles

HWTS Intervention Type	Number of Citing Articles
ALL FILTERS	**35**
Ceramic pot filters	13
Biosand filters	12
Membrane filters	8
Sand filters	6
Ceramic candle filters	5
Miscellaneous filters	3
DISINFECTION	**24**
SODIS	8
Boiling	5
UV radiation	5
Sodium hypochlorite	2
Sodium dichloroisocyanurate (NADCC)	2
Hypochlorous acid	1
Silver	1
Iodine resin	1
OTHER	**3**
Natural coagulants	2
Solar distillation	1

Returning to the content of the Sobsey 2002 citation instances within the citing articles, I will start with an overview before returning to the citations that focus on what was said by Bartram in the foreword. In Table 10 below, I've divided the citation instances into those that focus on specific HWTS interventions and those that focus on broader HWTS topics. Note that some articles cited Sobsey 2002 more than once, so there are more than 82 citations in total.

Table 10. Citations of Sobsey 2002

HWTS Interventions			Other	
Focus of Citations	**Number of Citations**		**Focus of Citations**	**Number of Citations**
Boiling	8		Diarrheal disease reduction/prevention	12
SODIS	4		Range of HWTS options available	12
Ceramic Filters	3		Endorsement of HWTS	9
Chlorine	2		Recontamination	9
Miscellaneous filters	2		Interim solution	8
Biosand filters	1		Limitations	6
Silver	1		New approach	5
Solar Pasteurization	1		Diarrheal risk factors	2

The citations that focused on specific HWTS interventions were straightforward, citing Sobsey on information that supported the interventions being discussed. For example, several articles presented boiling as likely the oldest and most widely practiced form of HWTS.[159,160,161,162] An article on ceramic water filters cited Sobsey 2002 when stating that these filters are one of the top five treatment options, reducing turbidity and bacteria by more than 90%.[163] Although HWTS-focused articles made up the majority of Citing Articles for Sobsey 2002, HWTS interventions did not dominate the content of the citations themselves in the same way. In Table 10, one can note a number of the "other" citation topics – that is, not a specific HWTS intervention – were the focus of citations more frequently than boiling, the most commonly discussed HWTS intervention. For example, Sobsey 2002 was cited in 12 instances in which authors mentioned the existence of a range of available HWTS options, an objective (as opposed to subjective) observation.

In another 12 instances, authors cited Sobsey 2002 when pointing to the evidence available on the diarrheal disease impact of HWTS. Although at a glance these citations are similarly objective, they are problematic for a couple of reasons. First, they cite

Sobsey 2002 with the intention of supporting the argument that there is evidence on the ability of HWTS interventions to reduce diarrheal disease when, in fact, Sobsey pointed out in this publication that the majority of interventions lacked such evidence. Secondly, the way in which four of these studies cite Sobsey 2002 is misleading. Reygadas et al. 2015 and Ojomo et al. 2015 cite Sobsey 2002 among a list of other publications by saying, "several studies have found" or "some studies have shown," from which readers may infer that Sobsey 2002 was a study in itself that generated data and led to these conclusions.[164,165] Thompson and Khan 2003 cited only Sobsey 2002 when saying "several studies,"[166] and Panda et al. 2014 when saying "clinical trials,"[167] which may lead the reader to infer the same, but if not, at the least it credits Sobsey 2002 with the findings that are summarized in that publication as opposed to crediting the authors of the original articles/studies. It is likely that citation instances focusing on other topics presented similar issues. As a result, checking the content and nature of every citation is recommended for future research.

Returning to the foreword, of the 82 citing articles, nine cite Sobsey 2002 in reference to Bartram's endorsement of HWTS, as you see in Oyanedel-Craver et al. 2008:

> "A recent review of the literature sponsored by the WHO concludes that simple, socially acceptable and low-cost interventions at the household (point-of-use) and community level have the potential to significantly improve the microbial quality of household water and reduce the risk of diarrheal disease, dehydration and death, particularly among children."[168]

In many of these citations, the wording used is very similar to that of Bartram, often reading almost as if it were quoting the foreword.

Another eight articles cite Sobsey 2002 with respect to Bartram's discussion of HWTS as an "interim" approach while waiting for the long-term solution of piped, treated water. For example, Brown and Sobsey 2010 say:

> "Conventional piped water systems using effective treatment may be decades away in much of the developing world, meaning that many of the poorest people must collect water outside the home and are responsible for managing (e.g. treating and storing) it themselves at the household level."[169]

Although only about 10% of the citing articles referenced Sobsey 2002 to assert HWTS as an interim solution, the positioning of HWTS in this way has become increasingly prominent. The only instance of HWTS being discussed as an interim solution published before Sobsey 2002 that I was able to find was Reiff et al. 1996.[170] This argument is now common in the scientific literature[171,172,173,174,175] and grey literature.[176,177,178,179] Further, it is often heard in discussions at HWTS forums such as the 2013 West Africa Regional Conference and the Annual Meeting of the Network at the 2015 Water and Health Conference at UNC-Chapel Hill, as well as during other sessions at the conference.

From this exploration and analysis of the content of citations, it is made clear that Sobsey 2002 was, in many cases, cited very differently from how Quick et al. 1999 and Fewtrell et al. 2005 were cited. Of course, the content of the publications was different, with Quick et al. and Fewtrell et al. providing evidence-based analysis and results while Sobsey provided an overview and discussion of the status of HWTS and of specific HWTS options. It makes sense, therefore, that for the RCT publication as well as the systematic review and meta-analysis, the majority of citation instances focused on results and findings as opposed to discussion points.

As noted above, many of the citation instances for Sobsey 2002 were similarly objective. However, it was found that 14% of these citations went against the intent of Sobsey 2002, and some also cited Sobsey 2002 in a way that was misleading and/or did not appropriately credit the original study. Furthermore, 20% of the citation instances focused on discussion points from the foreword, written by Jamie Bartram. In this way, Sobsey 2002 was relied upon in the scientific literature to support and move forward discussion points around HWTS that were not necessarily based on evidence-based research.

From experience working in the non-academic part of the HWTS sector, I have found citing grey literature, such as publications from the WHO or UNICEF, instead of the original source, to be common practice outside of scientific literature as well. This is a practice that perpetuates itself. To further exhibit this, I will provide an example outside of, but adjacent to, this collection of literature. In the WHO report on Round I of the Scheme, the background section cites a WHO document as the reference for the estimate of 502,000 diarrhea deaths in low-and middle income countries that can be attributed to unsafe and insufficient drinking water.[180] The WHO document is actually a report that is intended to summarize the findings of a series of five articles that were published in Tropical Medicine and International Health. The estimate of diarrhea deaths due to insufficient and unsafe drinking water originally comes from one of these articles: Bain et al. 2014.[181] This failure to cite the original source is a mistake, and one that may be perpetuated, but it is not terribly worrisome in itself.

What is worrisome is that this number was likely taken from the executive summary, where it is clearly and prominently presented, and if this piece of information had been on hygiene instead of water, the number would have been missing a critical piece of information. The executive summary of the WHO report states that 297,000 deaths can be attributed to inadequate hand washing. It fails to include the fact that this estimate is not statistically significant; that is, the confidence interval for this estimate includes zero, which is an important piece of information. The report does include this later in the document, but it is likely to be overlooked, particularly by those looking just for the key takeaways in the executive summary. It is clear that instances such as these in which the original source is not cited (and, therefore, likely not read) not only fail to recognize the original research but may also unintentionally lead to misinformation. This can certainly also happen in scientific literature, but based on the above analysis, it appears to be a more significant concern in the grey literature.

Limitations

There were many limitations that prevented a fully functional and complete mapping of the connections within this collection of literature and specifically the Cited References for Citing Articles. For the most part, these limitations stem from one issue: inconsistent use of unique identifiers such as ISSN or DOI for references cited. Because a unique identifier was not provided for each cited reference, the process of identifying duplicates and cleaning the list of Cited References was a manual, imperfect process. Furthermore, lack of unique identifiers for Cited References made it infeasible to write a code that identified instances in which an RCT cited the Citing Article of another RCT or a Citing Article cited another Citing Article. As a result, these connections were not fully represented in the visualization and could not be systematically explored and analyzed.

Not having unique identifiers for Cited References also made it more infeasible to expand the collection one generation backward – to the Cited References of the RCTs – and one generation forward – to the Cited References of the Cited References, limiting the scope of this research. As a result, I failed to capture relevant articles such as Souter et al. 2003, which was an article on the P&G Purifier of Water.[182]

Grey literature such as Sobsey 2002 proved particularly hard to track. As noted previously, the list of Citing Articles obtained from WoS was found to be incomplete. To my knowledge, unique identifiers are never used for grey literature such as publications from the WHO or UNICEF. So whereas it may be possible to increase the use of DOIs in the Cited References for scientific articles and thereby make these articles easier to track and connect, doing so for grey literature would require an entirely new practice among those publishing and citing this literature. However, given the issues identified above with respect to the citation of grey literature, I would emphasize the importance of exploring a more systematic means of citing this literature.

2.4 Conclusion

In the HWTS literature, articles on RCTs evaluate a specific HWTS option with respect to diarrheal disease impact. Systematic reviews and meta-analyses compile the findings of RCTs over the years into one set of numbers summarizing this impact. Grey literature translates scientific literature for practitioners and policymakers. Although these are generalizations, the intent is to point out that each publication is a snapshot, a piece of the larger conversation that is then passed down the line, through the sector, interpreted and translated according to a given actor's interests and needs. And each piece of the conversation has the potential to affect the conversation's course, its tone, the roles of its participants, and the actions that are taken as a result.

Within this conversation, pieces are treated differently. This analysis found that when the RCT publication or systematic review and meta-analysis were cited, these citations largely focused on the results and findings, with some citations focusing on discussion points made by the authors in response to these findings. The piece of grey literature on the other hand, was cited differently, with a greater emphasis on discussion points and sometimes even a misinterpretation or incorrect citation of what was presented. In analyzing the citations of Sobsey 2002, we found that this publication was used in the scientific literature to back up arguments in support of HWTS that were not necessarily based on evidence-based research. Specifically, the argument for scaling-up HWTS as an interim solution has been supported by citing Sobsey 2002, although this citation is actually drawn from the foreword by Jamie Bartram. We'll see this argument again in Chapters 3 and 4.

Given the prominence of non-academic players such as the WHO and UNICEF in the HWTS sector and the influence that grey literature publications have on the conversation, there is a need, moving forward, to better understand the interaction between the different actors who are involved in generating the different types of literature and the roles they play outside of the literature. To be able to better capture the conversation, its path, and its evolution over time, there is a need to create a more effective means of keeping track of the different types of literature and connecting them to each other through the consistent use of unique identifiers both in the publishing and the citing of this literature. Such practices would benefit other areas of research and expertise as well. Because of limitations with respect to connecting publications within this collection of literature as well as time and resource limitations with respect to accessing the complete content of each publication within this collection, this analysis was a snapshot itself, or rather a flipbook of snapshots. But it's one that can be built upon to better understand how knowledge around HWTS is created. Given the potential impact of HWTS, it is a matter of good practice to understand this process and its influence on the sector's actors and the decisions and actions they take.

3 Practice: Efforts to Scale-up HWTS in Ghana

"By 2020, 50 countries have achieved country-wide scale up of project-based HWTS."[183]

3.1 Introduction

In the previous chapter, we explored the overlap and interplay between researchers, policymakers and practitioners in the generation, documentation and dissemination of knowledge on HWTS through the literature. Research and publications on HWTS help to advance and disseminate knowledge within the sector. Ultimately, however, the sector as a whole is interested in moving beyond HWTS as a concept to HWTS as a product that, when used by households to treat water, will reduce exposure to waterborne pathogens and thereby improve health. In this chapter, we will focus on the production and dissemination of HWTS products, looking at Ghana as a critical case. But first, why HWTS? And why Ghana?

As we saw in the previous chapter, HWTS has been discussed in the literature as an interim measure for providing safe water to populations currently not served by centrally treated, piped water delivered into the home. The latter is seen as the "ideal solution for minimizing waterborne disease."[184] While repeatedly paying homage to this ideal and setting it forth as the long-term goal, proponents of HWTS argue that HWTS has the potential to contribute to immediate improvements in health for those currently without access to safe water.[185] With respect to policy measures and government responsibility for provision of services, proposing HWTS as an interim measure while working toward the long-term goal of piped treated water allows HWTS supporters to emphasize that they are not arguing for the diversion of resources away from centralized treatment facilities and the infrastructure required to deliver treated water into homes.[186]

And, in fact, there is no evidence that such diversion occurs[187]. At the same time, proponents argue that unserved populations have long had to take charge of their own water supplies, and they set forth HWTS as a way to empower these populations to control the quality of their drinking water and thereby improve the health of their families.[188,189] So, HWTS is an immediate, empowering solution to the need for safe water. What are we waiting for?

Within the context of water and health challenges and the potential contribution of HWTS toward addressing these issues, I would argue that Ghana serves as a critical case. The country has made significant progress in increasing access to improved drinking water – it actually met target 7C of the Millennium Development Goals (MDGs) with respect to water, going from 56% of the population with access in 1990 to 78.6% in 2013.[190] Much of this progress is credited to efforts carried out under the Urban Rural Water Management Programme, which included the rehabilitation, increased capacity and new construction of water treatment plants as well as the installation of boreholes. But the country still has significant work ahead when it comes to achieving "universal and equitable access to safe and affordable drinking water for all" as set forth by the Sustainable Development Goals (SDGs).[191] Importantly, this goal goes beyond achieving access to an improved source, as in the MDGs; specifically, the improved source must also be located on the premises and provide water that is free of fecal contamination and available whenever it is needed.[192]

Looking at equitable access, disparity in access to an improved water source between urban and rural areas has decreased from 47% greater access in urban areas in 1990 to 16.4% greater in 2014. However, it is important to remember that access to an improved source does not guarantee access to safe water at the point of use, where greater disparities persist. Furthermore, within the designation of "improved," sources can range from a protected dug well to a piped household connection. As of 2014, 16.4% of urban and only 1.7% of rural populations in Ghana had access to piped water into their dwelling, yard or plot.[193,l] This is where we can expect to find significant health benefits over other improved sources.[194] And ultimately, contamination is a threat as long as water must be collected, transported, and/or stored before use. Therefore, in addition to the populations using unimproved sources for drinking water, those using improved sources could stand to benefit from the use of HWTS. HWTS has not achieved significant scale in Ghana, however, with only 5.3% of urban and 2.5% of rural populations reporting use of an appropriate treatment method.[195,m] In fact, these numbers have decreased from 6.8% of urban and 10.2% of rural populations reporting use of an appropriate treatment method in 2008.[196] And so, while Ghana has made significant gains in access to improved drinking water, water quality will receive increased attention moving forward in the context of the SDGs. This context combined with limited access to piped water and challenges with respect to contamination of collected drinking water make HWTS a potentially valuable contributor to providing access to safe water.

Given the potential role for HWTS in Ghana, how can it be scaled up? First, let's define what it means to scale up HWTS. In the 2009 WHO report *Scaling Up Household Water Treatment Among Low-Income Populations*, Clasen defines effective scale up of

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[l] It is interesting to note that access has decreased in both urban and rural areas since 2008, when 27% of urban and 2.2% of rural households had access to piped water in their dwelling, yard or plot (GSS, GHS and ICF Macro 2008).

[m] In the Ghana Demographic and Health Survey, the following are included as appropriate treatment methods: boiling, chlorination, flocculation with alum, straining through a cloth, and filtration with a ceramic, sand composite or other filter.

HWTS as not only coverage but also uptake, meaning that it must not only be made available to but also be used correctly and consistently by the target population.[197] As to how to achieve scale-up, the consensus appears to be that a mixed approach will be required that draws on the strengths and capacities of the public sector, non-governmental organizations (NGOs) and the private sector.[198,199,200] In a mixed approach, these actors would work together to pursue both non-commercial and market-driven strategies to disseminate HWTS interventions. These strategies rely on three different approaches: (1) distributing products for free, (2) providing products at a subsidized cost that supports partial cost recovery, and (3) selling interventions through commercial channels at a price that covers all costs and includes a profit margin.[201]

But outside of statistics and the literature on scaling up HWTS, what do attempts to produce, distribute and implement HWTS on the ground actually look like? And what can we learn from these attempts with regards to the practicality of a mixed approach and its likelihood of success?

In this chapter, we will investigate efforts to disseminate three HWTS products in Ghana. Although these products differ in many ways - e.g. treatment technology, cost, manufacturer - the attempts to bring them to scale share two important goals: (1) reaching vulnerable populations; and (2) achieving scale through commercialization. These efforts and their common goals allow for an in-depth exploration of the reality of HWTS scale-up in Ghana through a mixed approach. I will propose that, in Ghana, commercialization, if successful, will reach the urban, middle class, which is the population most easily reached by centralized, treated piped water, thereby confirming concerns that HWTS will take away from government commitment to the stated long term goal. Bringing HWTS to scale in a way that reaches the target, vulnerable populations that may never be served by centralized, treated piped water will require long-term commitment from government, donors and NGOs.

3.2 Products

The three products that I have selected as case studies are those for which distribution and implementation efforts were ongoing in Ghana during the time of my fieldwork from 2010 − 2013: LifeStraw® Family 1.0, Hydraid Biosand Filter and the ceramic pot filter. Although all three achieve treatment through filtration, these products are distinct from each other not only with respect to technical specifications but also when it comes to their development, production and dissemination. Here, I will briefly introduce each product, presenting information on its production, treatment mechanisms, specifications and performance, while saving the details on their distribution and implementation in Ghana for the case studies later in the chapter.

3.2.1 LifeStraw Family 1.0

The LifeStraw Family (LSF) 1.0 is a hollow fiber membrane filter produced by the Swiss-based company Vestergaard Frandsen (now known simply as Vestergaard). Vestergaard is a for-profit company whose main product is mosquito bed nets, which it is well known for and sells millions of each year.[202] The company first got involved in water filtration through a collaboration with the Carter Center in 1996, when it produced a simple pipe filter with mesh in it as part of the Carter Center's Guinea-worm eradication campaign. This filter served as the inspiration for the LifeStraw personal, a portable water filter for individual use, which was launched in 2005.[203] The LifeStraw Family (LSF) 1.0 was launched by the company in 2008 for water treatment at the household level.[204] The filter's membrane technology was invented in Belgium; as of 2010, the LSF 1.0 was constructed in Vietnam, using parts from China and Vietnam, and then shipped from Vietnam to the point of sale.[205] The filter costs about US$25 wholesale.

In Figure 9 below, we can see the membrane cartridge at the end of a meter-long plastic tube, which hangs from a 2-liter bucket into which the user pours the untreated water. An 80-micron pre-filter in the bucket removes any large debris and particles. The water then flows down the plastic tube, and the hydraulic head drives the water through the membrane cartridge and out of the blue tap, when the tap is open. The ultrafiltration membrane has a pore size of 20 nanometers, which removes contaminants by size exclusion. That is, if a particle or pathogen is too big to fit through the holes in the membrane, then it cannot pass through the membrane. The red bulb at the bottom of the cartridge can be squeezed to backwash the membrane, after which the red tap is to be opened to release the backwash water.[206] The filter is designed to treat 18,000L, and a laboratory assessment determined a mean flow rate of 8.8L/hour over this design life.[207]

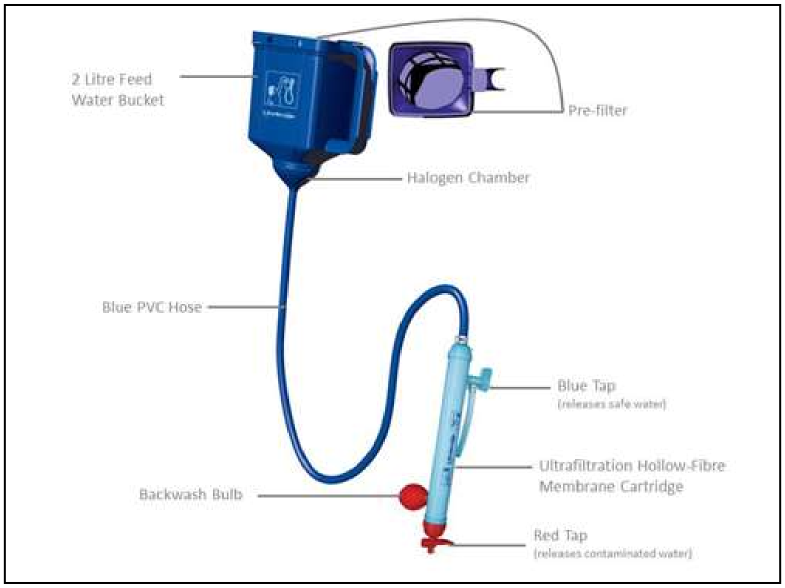

Figure 9. LifeStraw Family 1.0 Components[208]

With respect to efficacy, LSF 1.0 meets the U.S. Environmental Protection Agency (EPA) requirements for bacteria, viruses and protozoan cysts, achieving 6.9 log reduction for *Escherichia coli*, 4.7 log reduction for MS2 coliphage, and 3.6 log reduction for *Cryptosporidium oocysts.*[209] It has also been found to be microbiologically effective in the field. In a randomized, double-blinded, placebo-controlled trial, monthly testing found 2.98 log reduction in thermotolerant coliform levels as well as a constant flow rate. This study also found a high rate of compliance, with 76% of households reporting that they had used the filter that day or the day before, 14 months after filter distribution. However, this did not guarantee *consistent* use, as 83% of adults and 95% of children reported drinking untreated water the day before. Furthermore, the authors concluded that there was not significant evidence that LSF was protective against diarrhea.[210] A 2015 systematic review and meta-analyses of water quality interventions by Clasen et al. estimated a 31% reduction in diarrhea; it is important to note, however, that this analysis graded the quality of evidence for LSF performance to be low.[211]

3.2.2 Hydraid Biosand Water Filter

The Hydraid® BioSand Water Filter (Hydraid) is produced by the Michigan-based company Cascade Engineering. Hydraid is a plastic version of the biosand filter that was traditionally made of concrete, as designed by Professor David Manz at the University of Calgary in the early 1990's.[212] Given the challenges of producing and distributing concrete filters at a large scale, the plastic version was developed in hopes of addressing the concrete version's limitations.[213] The plastic housing can be centrally produced at a much larger scale and shipped worldwide, unlike the concrete housing, which is intended for local production and is too heavy to move long distances. A fully assembled Hydraid filter weighs about 135 pounds, as compared to a 300-pound fully assembled concrete filter.[214] The filter's internal design remains the same, with the same media specifications (e.g. grain size, sand depth), standing water depth and instructions for installation and use (See Figure 10). The plastic filter body is produced in the Cascade Engineering factory in Michigan and then shipped to the port of the country of implementation. Unless the distributor in country has access to a reliable quarry for sand and gravel that meets specifications, the filter media is also shipped with the filter bodies.[215]

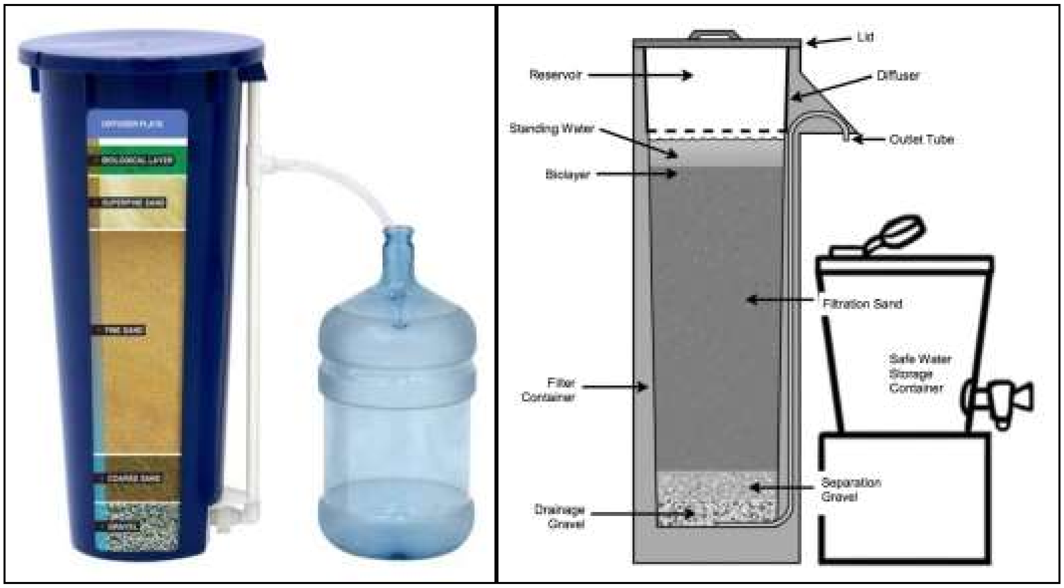

Figure 10. (a) Hydraid Biosand Water filter, (b) Concrete biosand filter *diagrams not to scale[216, 217]

As with LSF 1.0, hydraulic head drives the water through the filter, but unlike LSF 1.0, the biosand filter is designed for a resting period in which the dosed water remains in the filter until the next dose is poured in (minimum 1 hour), so the water coming out of the filter is that which was in the filter before dosing. The filter is designed to last over 10 years and filters water at about 48 liters per hour.[218] Microbiological contamination is removed through four mechanisms: mechanical trapping, predation, adsorption and natural death. The biolayer, which is the layer of microbes that grows on top of the filtration sand, is critical to the microbiological performance of the filter. Without a biolayer, the filter removes 30-70% of pathogens, largely through mechanical trapping and adsorption, while with a fully-grown biolayer (after about 30 days), a filter will remove up to 99% of pathogens.[219]

More specifically, the biosand filter has been found to achieve 1.9 log reduction (98.7%) of *E. coli* (bacteria),[220,221] 0.85 log reduction of bacteriophage MS2 (virus),[222] and 2.9 log reduction of Cryptosporidium oocysts (protozoa).[223] Three randomized, controlled trials have been performed on Hydraid, with the following, statistically significant findings regarding microbiological effectiveness and diarrheal disease reduction: 0.28 log *E. coli* reduction and 47% diarrheal disease reduction (Dominican Republic);[224] 1.2 log *E. coli* reduction and 59% diarrheal disease reduction (Cambodia);[225] and 1.5 *E. coli* log reduction and 60% diarrheal disease reduction (Ghana).[226] As an important note, the study in the Dominican Republic that found a much lower reduction in *E. coli* measured the microbiological quality of all water that the household designated for drinking, as opposed to the other studies, which measured the quality of water directly from the filter outlet. Clasen et al. 2015 estimated a 53% reduction in diarrheal disease by biosand filters and graded the quality of evidence to be moderate. With regards to compliance, the studies in Cambodia and Ghana reported 89% and 97%, respectively, with households reporting use. Although these studies were only on the order of 6 months, unpublished studies have found greater than 85% compliance up to 8 years after filter implementation.[227,228]

3.2.3 AfriClay Filter

The AfriClay Filter is a ceramic pot filter that is produced in the Pure Home Water factory in Northern Ghana by local workers using locally sourced materials. Although the filter size and shape has increased, the filter basics remain the same as the ceramic pot filter as it was originally envisioned by Fernando Mazariegos in 1981 and eventually produced at scale by Ron Rivera and Manny Hernandez and their organization Potters for Peace.[229] As of 2012, Pure Home Water was one of 36 factories in 18 countries producing ceramic pot filters.[230] There are now over 50 factories in more than

30 countries.[231] The price of the AfriClay filter in 2012 was 50 Ghana cedis (GHC), which was about US$25.

The AfriClay Filter consists of the clay filter pot, a plastic bucket, a lid and a tap (See Figure 11). Replacement costs for the different parts are: GHC25 for the filter pot, GHC20 for the plastic bucket, GHC3 for the lid and GHC3 for the tap. For treatment, water is poured into the filter pot and then allowed to pass through the pores of the pot, driven by gravity, and collected in the storage bucket below, where it can be stored safely until use, at which point treated water can be obtained from the tap on the bucket. According to Pure Home Water, the removal mechanisms are: physical straining, as with LSF 1.0 and Hydraid; sedimentation or adsorption, in which particles settle onto or stick to the clay; and inertia, in which friction in the pores prevents particles from passing through. Finally, the AfriClay filter is coated in colloidal silver, which also kills bacteria and serves as a disinfectant to prevent bacterial growth on the pot.[232] The design flow rate for a ceramic pot filter is 1-2 liters per hour, and the typical lifetime of a filter is 2-3 years.[233]

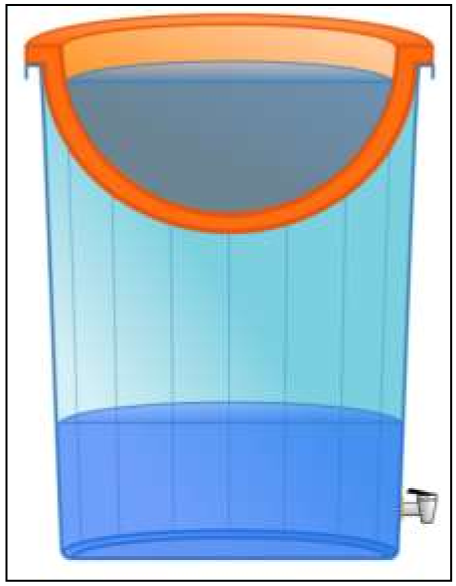

Figure 11. AfriClay Filter Cross-Section[234]

With respect to microbiological removal in the lab setting, studies have repeatedly found that the ceramic pot filter can achieve greater than 2 log removal of bacteria.[235,236,237] Filter performance with respect to virus removal, however, varies widely among studies, from as low as 0.1 log[238] to greater than 2 log.[239,240] In field evaluations, ceramic pot filters have achieved approximately 1 log removal of bacteria.[241,242] The health impact of ceramic filter interventions has been extensively studied. The 2015 systematic review and meta-analysis by Clasen et al. identified 8 trials that met inclusion criteria (as compared to 4 trials for biosand filters and 3 trials for LSF 1.0). This analysis estimated that ceramic filters led to a diarrheal disease reduction of 61%. Nine of the 12 trials included in the analysis measured compliance, although indicators differed, with some relying on self-reporting by households and others measuring the quality of water intended for consumption, for example. By these different measures, compliance ranged from 55% up to 100%.[243]

3.3 Field Work

This chapter is a compilation of what I've learned through interviews and observation, supported by a review of the literature that builds off of that performed for the previous chapter. From December 2009 to December 2014, I conducted 45 semi-structured interviews with 28 interviewees, in person or over Skype or telephone. A complete list of these interviews can be found in Appendix D. I used a semi-structured format in order to provide adequate structure to the interview while also allowing me to ask further questions on areas in which respondents had more knowledge and experience.[244] Further, this format provided a better means for respondents to express themselves freely and in their own words.[245,246] For the most part, the respondents with whom I requested interviews were those who had played or continued to play a role in the development, production, distribution and/or implementation of the three HWTS products that are the focus of this chapter. However, I also interviewed others active in the HWTS sector, particularly those involved in the same process for other HWTS products. Interviews were recorded, with permission and according to the Johns Hopkins University Institutional Review Board guidelines, and then transcribed. If the respondents did not want to be recorded, I took notes. The transcriptions were made available for respondents to review and comment on, allowing for requests for confidentiality.

In-person interviews and observations took place in Ghana - specifically, Accra, Tema and Tamale - in July-August 2010, May 2011, September-December 2012, and May 2013, as well as in other locations including Boston, Massachusetts; Chapel Hill, North Carolina; Grand Rapids, Michigan; and Kakamega, Kenya. The first two trips to Ghana in 2010 and 2011 were largely dedicated to supporting research by Opryszko et al.

on community-level water treatment kiosks and their impact on household drinking water quality.[247] Data collection for this research consisted of household surveys, key informant interviews and focus group discussions, all of which I contributed to planning, organizing and carrying out. These two periods of fieldwork were instrumental in establishing an understanding of the broader context in which WASH, and more specifically HWTS, interventions were taking place in Ghana. In the latter half of my 2011 trip, I began more HWTS-focused work, seeking out HWTS stakeholders in Ghana and beginning to establish connections within the sector to facilitate future fieldwork and interviews.

My trips in 2012 and 2013 were dedicated entirely to research on HWTS. In addition to conducting interviews, in September-December 2012, I observed separate, village-level implementation of the LSF 1.0 and AfriClay filter in rural areas outside of Tamale in the Northern Region of Ghana as well as trial marketing of Hydraid in Accra. I also participated in the 2013, 2014 and 2015 Annual Meeting of the International Network to Promote HWTS (the Network), which is hosted at the University of North Carolina-Chapel Hill (UNC) Water and Health Conference every October. In October 2012, I volunteered for two weeks as a Field Manager for the Vestergaard Carbon for Water Campaign, which will be discussed later in the chapter as an example of LSF 1.0 being scaled up. And in May 2013, I attended the West Africa Regional HWTS Workshop, which was also attended by representative for LSF 1.0, Hydraid, and the AfriClay filter, along with a wide range of other HWTS stakeholders. There was significant overlap between the field work for this chapter and for the chapter that follows, which focuses on HWTS policy development in Ghana.

Although my fieldwork ended in 2013 and the last interview I conducted for this chapter was in December 2014, I have remained actively engaged in the global HWTS sector as well as the Ghanaian HWTS sector not only through attending the UNC Conference and Annual Network Meetings but also through continued review of the literature and, more importantly, interaction, communication and collaboration with sector stakeholders. This continued engagement has been facilitated by my role as Knowledge and Research Coordinator for the Centre for Affordable Water and Sanitation Technology, which I began in August 2015.

3.4 Achieving Scale-up of HWTS

3.4.1 Background

In the introduction, I provided some of the arguments for scaling-up HWTS. Is there evidence to support this scale up? A 2006 Cochrane review by Clasen et al. analyzed the evidence on the reduction of diarrheal diseases by interventions to improve water quality. In this review, the authors pointed out weaknesses in the available evidence, including reporting bias, the reliance on unblinded trials, and the limited duration of trials. Furthermore, they highlighted the need to demonstrate not only health impact but also other factors critical to the success of an intervention, such as affordability, acceptability, and uptake.[248] Several years later, Wolf-Peter Schmidt and Sandy Cairncross, two prominent HWTS researchers at the London School of Hygiene and Tropical Medicine, wrote a critical review evaluating whether there was sufficient evidence for scaling up HWTS in poor populations. In this analysis, Schmidt and Cairncross looked at the evidence on the acceptability and scalability of HWTS as well as the potential non-health benefits and adverse effects. They concluded that "widespread promotion of HWT is premature given the available evidence."[249] This conclusion and the points made in support of it were quickly disputed and addressed by other prominent HWTS researchers - Thomas Clasen, Jamie Bartram, John Colford, Stephen Luby, Robert Quick and Mark Sobsey - in a published comment on the critical review.[250]

More recently, a 2015 Cochrane review by Clasen et al. replicated the 2006 analysis on an updated pool of evidence on the health impact of water quality interventions. Simply put, this review found that HWTS is effective. The different household intervention types - water disinfection products, household filtration systems and solar disinfection - were all found to reduce diarrhea, with reductions ranging from 23% for chlorination products to 61% for ceramic filters. Equally important to the discussion around evidence supporting HWTS, the authors also evaluated the quality of evidence available for each water quality intervention type, which covered not only HWTS but also improvements to water sources and treated, piped systems. For the most part, the evidence for the different HWTS interventions was determined to be of "moderate quality," with the exception being the "low quality" evidence for chlorination products. In contrast, the evidence for source-based interventions was found to be of "very low quality." To be clear, this evaluation of the quality of evidence, as determined by Clasen et al., does not have implications for the effectiveness of the interventions but rather the extent to which these interventions have been studied and the quality of evidence produced by these studies. From the analysis by Clasen et al., one can conclude that the evidence in support of HWTS is much stronger than in the past and that this evidence is stronger than that for other water quality interventions. In short, the discussion continues and some issues with the available evidence (e.g. reporting bias, unblinded trials) remain unaddressed, but many are of the opinion that there is sufficient evidence in support of the scale up of HWTS.

As to how to achieve scale-up, I also briefly touched on the proposed mixed approach in the introduction. Let us now look at the rationale for such an approach, beginning with private sector involvement as a key element. The private sector is seen as a logical partner in achieving scale-up given its expertise in consumer research, product design, financing, logistics, marketing and sales.[251] It has also been argued that the private sector has the economic incentive to develop the products and delivery models needed to create and meet large-scale demand.[252,253] Market-driven approaches have been credited with achieving the majority of HWTS coverage, although this coverage has largely been at the middle of the economic pyramid as opposed to the bottom. These approaches include efforts not only by private, for-profit companies but also non-profit, social marketing organizations.[254] Social organizations promote products, practices and services that benefit public health, such as hand washing and use of condoms, using commercial marketing techniques, such as print media and radio and television ads.[255] Depending on the campaign, the product, practice or service may be sold or delivered at a price intended to cover costs or at a subsidized price intended to match willingness and/or ability to pay. There is evidence that interventions that use social marketing principles can achieve effective behavior change,[256] and such behavior change is critical to the uptake of HWTS interventions in order to achieve improved health.

In spite of the coverage achieved by market-driven approaches in addition to a swell of enthusiasm about the "fortune at the bottom of the pyramid"[257] in the broader development sector, the HWTS sector has been forced to realize that the most important target audience - vulnerable populations who bear the brunt of the disease burden and are the most likely to benefit from HWTS - lives on less than 3, 2 or even 1 dollar a day.[258,259] These populations are also often difficult to reach because they live in rural areas. In fact, 80% of those without access to improved water sources live in rural areas, often in sparse, remote villages.[260] Such populations will be difficult to reach through commercial strategies[261] and will likely rely on free or highly subsidized distribution of HWTS.[262] Furthermore, the time and resources required to achieve sustained behavior change among vulnerable populations make the bottom of the pyramid market less appealing to the private sector.[263] It is argued that NGOs are well positioned to help reach these populations given their existing programs and established presence in communities[264], and using these existing NGO networks can increase rural penetration by HWTS interventions.[265] The assumption is, however, that the private sector will still be involved in these non-commercial strategies, given that many HWTS options are manufactured by the private sector, with exceptions including locally produced biosand filters and ceramic pot filters. In the case of for-profit manufacturers, profits will still be made, but they will come from the sale of products to intermediaries such as governments, donors or NGOs, and not from poor consumers.[266] Therefore, considering the existing expertise of and resources available to the different actors (as well as their limitations), the common consensus is that achieving scale-up of HWTS will require collaboration between the different actors and the integration of non-commercial and market-based strategies.

In the rationale behind a mixed, collaborative approach to the scale-up of HWTS, there emerged a number of limitations that affect the different actors' abilities to reach certain populations. These are just some of the many challenges that are faced by those working to increase HWTS coverage. Perhaps most important to truly achieving scale is the challenge of achieving uptake - also known as correct, consistent use - after getting an HWTS intervention to the end user through any channel.[267] Simply put, getting a filter into a household will do nothing to improve health if the filter is not used correctly by the household to treat water consistently enough that they have sufficient drinking water for all household members every day of the week. As discussed in the previous chapter, correct use of a HWTS intervention requires the knowledge and the ability to use the intervention correctly. Furthermore, the intervention must be easy to use and require minimal time to treat water to increase the likelihood that it will be used consistently.[268,269,270,271] The nature of household water treatment requires daily effort, indefinitely, on top of collection of water from the source, and households that face a wide range of competing priorities and may not see the health benefits of HWTS due to sickness resulting from other diarrheal disease transmission routes, may slip out of the practice as a result.[272]

Unfortunately, uptake is not only difficult to achieve but also very difficult to measure, even in rigorous, randomized controlled trials, much more so during regular distribution and implementation in the field. As a result, very few HWTS implementers keep track of and report the number of users; instead, the common practice is to estimate the number of users through a simple calculation starting with number of units sold or implemented, multiplying it by the treatment capacity of a unit (e.g. 10L/chlorine tablet), and dividing it by the number of liters per person per day (e.g. 2L/person/day). In spite of pointing out this limitation in the 2009 WHO report on scaling up HWTS, author Thomas Clasen perpetuates the problem by performing this calculation himself to estimate the number of users at year end for chlorine tablets and flocculant disinfectant sachets.[273]

One can also find examples of such estimations in promotional literature for some HWTS products. For example, the U.S. Centers for Disease Control and Prevention's (CDC) fact sheet on the Safe Water System, which uses liquid chlorine for household water treatment, states "a volume of products sufficient to treat 137 billion liters of water (as of 2013) has been sold since 1998."[274] On Procter and Gamble's (P&G) Children's Safe Drinking Water (CSDW) website, which is the home for the P&G Purifier of Water flocculant disinfectant sachet, a blog post says, "10 billion liters of clean water have now been distributed,"[275] when in fact, this is not the case. 1 billion sachets of the flocculant disinfectant have been distributed,[276] but that cannot be directly translated into 10 billion liters of clean water, as that would assume that all sachets distributed were then not only used but also used correctly - following the correct treatment process on the correct volume of water. P&G went even further at the 2010 Clinton Global Initiative event in New York, where the P&G CEO committed to saving one life every hour in developing countries by providing 2 billion liters of clean water every year.[277]

Researchers have tried to more rigorously estimate the scale of household water treatment. In a 2010 research article, Rosa and Clasen used data on reported HWTS practices taken from national surveys and reports. But even this research had its limitations, as such data was only available for 67 countries; furthermore, not all of the surveys were nationally representative, and the data was on reported practices, which is subject to bias.[278] Because of the challenges to and limitations of data collection on uptake, it will be difficult to measure increased coverage as efforts continue to scale-up HWTS. It will be even more difficult to know whether HWTS scale-up efforts are achieving correct, consistent, continuous use and contributing to improved health and livelihoods.

3.4.2 Global Examples of Achieving Scale

Having explored the arguments for the scale-up of HWTS, the approaches by which the sector proposes to achieve scale-up, and the challenges to achieving meaningful scale-up and measuring the progress made, let us now look at two examples in which for-profit companies brought centrally manufactured products to scale. The two products we will be looking at are the flocculant disinfectant packet produced by P&G, called the Purifier of Water, and the membrane filter produced by Vestergaard, called the LifeStraw Family 1.0. Their associated campaigns are the Children's Safe Drinking Water Program and the Carbon for Water campaign, respectively.

Procter & Gamble Children's Safe Drinking Water Program

We'll start with the P&G Purifier of Water, which was born from a collaboration with the U.S. CDC in the late 90's and launched as a product in 2000.[279] This sachet of treatment chemicals – specifically, ferric sulphate and calcium hypochlorite – can remove microbiological contamination and turbidity through the combination of precipitation, coagulation, flocculation and disinfection. One sachet contains the chemical dose needed to treat 10L of water. [280] One can imagine the appeal of a consumable HWTS product in a packet to P&G, a company that has proven highly successful in scaling up household and personal care products in small sachets,[281] so successful, in fact, that as of 2011, it was the world's biggest consumer products company. After launching the product, P&G used commercial channels to test market the sale of the product in several countries. Tests at the village-level in Pakistan in 2002 found that the P&G packet could achieve a 60% market penetration rate, which catalyzed the launch of a high profile, commercial, urban-focused campaign in 2004 in collaboration with the Pakistan Medical Association (PMA). The PMA supported P&G efforts through a massive safe water social marketing campaign to encourage uptake of the product.[282]

In spite of these joint efforts, repeat purchases of the product were only about 5% six months after the campaign began. This was perceived by P&G as a failure, and the company made the decision to end the campaign and donate the remaining packets to Population Services International (PSI), a social marketing organization that then partnered with a Pakistani NGO to distribute the packets as part of their normal public health activities.[283] Some of the barriers to uptake that could have led to such a low market penetration by the Purifier of Water include the cost of regularly treating water with the product, the need to demonstrate how to use the product, and the time and effort required to treat water with the product,[284][n] which are in line with the points previously made about achieving correct and consistent use.

This commercial failure did not discourage the product's champion, Greg Allgood, who fought to convince P&G's CEO at the time that the Purifier of Water

[n] To treat water with the Purifier of Water, the user must add the sachet to 10 liters of water, stir it well for 5 minutes, let the water stand and settle for 5 minutes, pour the water through a clean cloth into a clean bucket, and then wait for 20 minutes before consuming.

should not be discarded entirely but rather morphed into a non-profit venture as a corporate social responsibility arm within P&G; this endeavor is now know as the CSDW program. P&G brought on PSI as a partner for its social marketing expertise and experience with local public health outreach programs. Allgood assured the CEO that partnering with NGOs and making use of their networks would help to improve market penetration, given that P&G's infrastructure apparently didn't reach that far into the field – a fact that I find surprising for the world's biggest consumer products company.

Through the CSDW program, the packets are largely sold at cost to NGOs who then sell them at a subsidized price, supported by PSI's social marketing efforts.[285] PSI's social marketing efforts, in turn, are more than 50% covered by governmental sources, namely the United States Agency for International Development and the United Kingdom Department for International Development.[286] The product has also been successful with respect to distribution in emergency settings,[287] in which it is presumably given out for free. And so, what began as a commercial, market-driven approach with social marketing support has become a non-profit endeavor with social marketing support, NGO involvement and government funding.

As discussed in the previous section, P&G recently celebrated the distribution of 10 billion liters of clean water. The promotion of the Purifier of Water through a non-profit approach has been touted as far more successful than the original approach, given that the for-profit model provided only 10 million liters of clean water per year whereas the new model provides more than 1 billion liters per year.[288] This statement gives me pause, however, given our previous consideration of the difference between distribution and uptake. In reality, P&G's non-profit approach to distributing the packets may have enabled them to distribute 100x more packets per year, but the company is unable to verify that all of these packets are, in fact, used, much less used correctly and consistently. In addition to talking about the liters of clean water provided, a case study on the P&G Purifier of Water framed as a discussion with Greg Allgood said, "Allgood remains charged with measuring the effect that PUR [Purifier of Water] has on sales of P&G products, external goodwill, employee recruitment, morale, and retention."[289] Yes, it is a business school case study, but what of the benefits to the end user through improved health? Not even an afterthought? Furthermore, this story leads me to ask - if the leading consumer products company in the world cannot achieve commercial scale up of a consumable HWTS product, then who can?

Vestergaard Carbon for Water Campaign

We turn now to another example of a commercial HWTS product being brought to scale, but through a campaign quite unlike that pursued by P&G. Vestergaard sought to scale up its LifeStraw Family 1.0 membrane filter but ran into road blocks with respect to financing their campaign. Vestergaard found that donor funding, which is generally intended to support a project for three to seven years, would be inappropriate, as the company intended to run a 10-year project.[290] At the same time, at a cost of $25 wholesale and likely $50-70 after distribution and marketing,[291] the LSF 1.0 was far too expensive for the target end users - vulnerable populations in the Western Province of Kenya - to purchase in a market-driven scale-up model, a non-starter before even considering whether or not the market existed for this product.[292]

Because of the target population's inability to pay, Vestegaard decided to distribute the filters for free and provide free support services throughout the life of the project. As a result, the company would need to find a way to not only cover the capital cost of the filters themselves but also the costs of running the program for 10 years,[293] which would include paying community health workers and drivers for the initial distribution, installation and training as well as establishing and running repair and replacement centers.[294] To cover these expenses, Vestergaard sought carbon financing, which had never before been employed for funding a water project.

Although water filters were new to the carbon finance scene, the company was able to follow an existing method that was originally intended for cookstoves that reduced burning wood as fuel, with an addendum that provided for its application to water treatment technologies. A key element that made carbon financing possible for this project was the concept of suppressed demand, which essentially meant that Vestergaard would receive credits not only for emissions reductions from the wood not burned by households that routinely boiled their water before filter distribution but also for the wood that would have been burned by households too poor to boil their water if they could have afforded the wood.

What was required to receive these credits was to show that households used their LSF 1.0 filter regularly. Because of the project's carbon financing, it was named the LifeStraw Carbon for Water campaign.[295] It would prove to be very controversial for a number of reasons, particularly the concept of suppressed demand, [296]but the intent is not to explore those reasons here.

Having secured carbon financing, Vestergaard invested $30 million to start the project, as it would not receive money from carbon credits until the project was up and running and independently audited to verify use. For the purpose of the audit, use meant the household was using the filter at least once per two week period.[297] After an extensive planning period, Vestergaard officially launched the Carbon for Water program in 2011 and distributed 877,505 filters in the Western Province of Kenya from April 26 to May 30 of that year. These households were said to represent 91% of those without access to safe water and altogether constituted more than 4.5 million people.[298]

To achieve such rapid and extensive distribution, Vestergaard hired 4,000 community health workers (CHWs) and the same number of drivers. These CHWs and drivers paired up to visit every household, train the household on how to use the filter and safely store the treated water, and install the filter in the household.[299] For the long-term, the company established a repair and replacement center in each of the 32 districts of the province to provide free support services when filters needed to be fixed, required replacement parts or needed to be replaced altogether. In addition to the project's 48 permanent, Kenyan staff, it also hires 4,000 CHWs and drivers, each, for its education campaigns that take place every 6 months.[300] In these 5 week campaigns, the CHWs focus on educating households on water, sanitation and hygiene practices as well as use, repair and replacement of the filters, as necessary.

As mentioned in the Field Work section, I volunteered as a field manager for two weeks of the October 2012 campaign. Here, I would like to draw from my experience to provide some insight into the scope and logistics of the campaign as well as the interaction that CHWs and field staff have with households during a campaign.

As a field manager, I was paired with a Kenyan Masters in Public Health (MPH) student, and together we were responsible for two of the 30 districts in the Western province. Each district has a District Coordinator and contains 5-10 sites. Each site has a Team Leader and anywhere from 2 to 30 educators, depending on the site size (with almost 3,000 educators in total for the October 2012 campaign). The goal of the October 2012 campaign was to reach 90% of the 877,505 households that had received a filter. As a field manager, I worked with my Kenyan MPH partner to manage the teams in our districts, address any issues that came up, and perform random spot checks in all of the sites in our districts. The purposes of the spot checks were to: verify the quality of education; identify and address any issues with specific CHWs; correct any misinformation or poor training; and collect data on use of the filters and other related habits. The last purpose corresponded with the upcoming carbon credit audit, as Vestergaard wanted to have an idea of how the program was going to perform and try to address any major usage issues before the audit.

With respect to the household education and training, in previous campaigns, the focus had been on drinking filtered water. For this campaign, the education messaging had been modified to include not only drinking filtered water but also using filtered water to wash hands and to wash fruits and vegetables - the three main health-related uses for safe water. While in a household, CHWs had a number of tasks to perform in addition to education: make sure that the filter was hanging properly so that the pre filter could be removed easily for cleaning; make sure that the pre filter was not clogged, and if it was, take the time to clean it and restore proper flow; make sure that the membrane cartridge was not clogged, and if it was, take the time to backwash as necessary to restore proper flow; make sure that no parts needed repair or replacement, but if they did, make note of it in the survey so that the service center could address the issue. As for the education, I've included below the key messages that educators were to share with households and the details and insight behind these messages.

1. *Use the filter appropriately. Clean the prefilter every day. Backwash every day.* CHWs were to cover the basic use of the filter, emphasizing that filtered water came from the blue tap and dirty water came from the red tap. Users were also told to clean the prefilter every day using a soft cloth and no soap. Backwashing was also to be performed every day, and users were instructed on the proper way of backwashing – squeezing the bulb until it's flat and then releasing and allowing it to refill fully before squeezing again, for a total of three times, then opening the red tap for 3 seconds. In my spot checks, appropriate backwashing remained a problem, with some people squeezing the red bulb three times quickly and others squeezing the bulb with the red tap open. Most knew to use a soft cloth and no soap when cleaning the prefilter, but some used soap, leading to faster clogging.
2. *Use filtered water for drinking, washing hands, washing fruits and vegetables, and carrying water to school and the workplace.* As I mentioned, in the past the focus had just been on drinking water, which they realized meant that people were not using the filter to its full capacity and filtering enough water to use for health-related purposes. The last use was added because many people do not bring water with them outside of the house and therefore consume unfiltered water, negating the health improvements of consuming filtered water.

3. *Do not use filtered water for cooking, making tea, doing laundry, watering livestock, etc.* This continued to be a problem, as many people wanted to use filtered water for other purposes since the water they collected was often very turbid. They wanted their ugali (corn meal-based dish) to be white; they wanted their white sheets to stay white; they wanted their tea to be dirt free. Many CHWs struggled with arguing against this.
4. *Filter enough water for each person to drink 8 glasses of water per day and for the family to have a 20L jerry can for handwashing and washing fruits and vegetables every day.* This volume of water was determined to be the amount per day is necessary to ensure that there's enough water for the three main health-related issues, although I do not know the calculations/background that led to this number. Almost none of the houses I visited for spot checks were filtering this amount, with some filtering less than 1L per person per day. Also, users were told to have an appropriately sized container. In spot checks, I found many people were still using 3L or 5L containers, which were far too small to achieve the necessary volume of filtered water per person per day, especially if being used by a family of 5 or more.
5. *Use a designated safe storage container. Never use the container to collect water from the water source. Clean the safe storage container once a week.* CHWs were to cover the standard reasons for using a designated safe storage container – to avoid recontamination – and the standard requirements for an appropriate safe storage container – small opening to prevent hands from recontaminating, a cover to prevent dirt from entering. Users were also told to clean the container once a

week and to allow the container to dry completely after cleaning. I was not clear on how they were to clean it – with bleach or soap or just filtered water.

6. *Wash hands before eating, after using the toilet, after changing a child's diaper, after handling livestock, before and after cleaning a wound, before and after taking care of a sick person, etc. Use soap when washing hands.* The CHWs were to cover all of the times when one should wash his/her hands. And they were to instruct people to always use soap when washing hands. This latter message sometimes was lost, as several people I interviewed said they only used LifeStraw filtered water for washing their hands because it protected against germs.
7. *Explain the health benefits of LifeStraw filtered water.* The CHWs were to discuss the following points: no diarrhea or typhoid; a healthy family can work more; girls and women have more time for school and work, respectively; reduced medical costs.
8. *Explain the Service Center, its phone number, and its location.* CHWs were to make sure that users knew about the service center in their district; that they could take their filter there if there was a problem or something was broken and needed replacement; that services were free. They were to explain its location and underline the contact information on the back of the calendar that each user received.

From my brief two-week glimpse into the logistics behind running a campaign of such scale, the responsibilities of the CHWs and field staff, and the expectations of households with respect to using the filters, it was clear to me the extensive amount of time and resources that would continue to have to be dedicated to this program to keep it running for its 10-year time frame. Furthermore, the cooperation and contributions of the government and local institutions throughout the campaign and during the times between campaigns were also critical to its continuation. In addition to the full-time local staff, Vestergaard also carried out a school program in 3,960 schools in the Western province and maintained a network of 1,300 community-based volunteers. The company also worked closely with and through the Ministry of Health, which included collecting data at selected health clinics and sharing this and other information with the Ministry of Health.[301]

Let us return now to the financing of the project through carbon credits. The first audit and verification of the project took place at the end of 2011 and evaluated the project's reduction in or avoidance of emissions - remember the suppressed demand caveat - over its first 6 months. For this audit, about 20,000 households were surveyed, with additional samples taken by an independent Kenyan research company and an international auditing company. Analysis of the survey data found a 91% usage rate (reported by the household and defined as at least once every two weeks) and with this use providing about 3 liters per person per day, which was used for the recommended activities discussed above. From these results, those verifying the project, including the Gold Standard Foundation, determined that Carbon for Water had reduced or avoided 1.35 million tons of carbon dioxide emissions, which doubled expectations.[302] An unspecified amount of these credits were purchased by JPMorgan Chase & Co. at a price that was greater than $11.48 per ton, although the actual prices was also unspecified. So, it remains uncertain whether the credits earned covered the initial investment of $30 million by Vestergaard.[303] I was able to determine that credits were issued in 2012 as well but information was not included on the number of tons reduced or avoided.[304]

And what of the benefits to the end user? As of October 2012, Vestergaard intended to evaluate health impact and was piloting a case-control study for children younger than 5 years old (a vulnerable population). The audit and verification process was not intended to measure filter effectiveness or the health impact of the intervention, but let's take a look at the information available to us. In the survey, 83% of households reported using the filter at least twice per week,[305] but one must take into account the potential for reporting bias, which has been found to significantly affect the actual versus reported impact of an intervention.[306] Furthermore, a recent quantitative microbial risk assessment performed by Brown and Clasen found that a decline in adherence from 100% of water consumed being treated to 90% being treated reduces the predicted health impact by up to 96%.[307] Considering the overall mean filtration rate for the LifeStraw Family 1.0 is 8.8L per hour paired with the fact that its upper container is 2.5L[308] and the household likely doesn't have the time to stand and wait to refill the upper container when it empties every 15-20 minutes, it is highly unlikely that using the filter twice per week (or even once per day) would be enough to provide an entire household with 2L per person per day to allow someone to consume 100% treated water every day. Achieving reduced diarrheal disease and improved health, then, remains uncertain.

Coming back around, however, to the intended focus of this example - achieving scale - the Carbon for Water campaign is a unique, resource-intensive approach to a massive, blanket distribution of a HWTS product. Like the P&G Purifier of Water and the Children's Safe Drinking Water program, it serves as an example of a for-profit company achieving large-scale distribution through non-commercial means, again because commercial scale-up was determined to be infeasible. However, as with P&G's efforts, it remains unclear that this program could be sustained in the long term and doubtful that Vestergaard has achieved the uptake required to reach meaningful scale and public health impact.

3.5 Case Studies in Ghana

Now that we have looked at two very different attempts by for-profit companies to achieve large scale distribution of HWTS products that, in the end, relied on non-commercial means, we'll now look at efforts to commercialize and scale up HWTS in Ghana, focusing on three specific filtration products: the LifeStraw Family 1.0 membrane filter produced by Vestergaard, the Hydraid biosand filter produced by Cascade Engineering, and the ceramic pot filter locally produced by the NGO Pure Home Water (PHW). For each of these products, I will first provide a brief history of the product and an overview of the technology and its performance as context before looking specifically at implementation activities in Ghana. The objective of this section is to learn from these efforts and identify challenges and limitations to scale up in Ghana before then exploring what is proposed in the HWTS-specific strategy that has been developed in Ghana.

3.5.1 LifeStraw Family 1.0

I will begin with the LifeStraw Family (LSF) 1.0, building off of what we've just explored in the Carbon for Water campaign in Kenya as an example of rapidly achieving scale - allowing, of course, for the lead up time for planning and financing the efforts. In contrast, activities around the LSF 1.0 in Ghana were of a much smaller scale. During my field research from 2009-2013, Vestergaard's West Africa Regional Office was located in Accra, and Michael Steene Lunde was the West Africa Regional Director. At this time, there were also regional offices in Kenya and South Africa. In 2013, Vestergaard consolidated its presence in Africa, closing its South Africa and Ghana offices, but even before this downsizing, implementation of LSF 1.0 in Ghana was limited and did not meet Mr. Lunde's expectations.

In my first conversation with Mr. Lunde in March of 2010, he expressed hope that LifeStraw Family 1.0 would be sold commercially, that it would soon be found on the shelves of big box stores - "the Walmarts of West Africa."[309] At that time, he was also interested in pursuing corporate social responsibility sales to mining companies. In Ghana's office, they were trying to set up a retail department, because at the time they were still very much relying on donor-financed purchases of the filters. Local sales staff would actively seek out a range of stakeholders, from the Ministry of Health to companies to NGOs. The Ghana office was also supported by the head office in Switzerland and the Washington, D.C. Office, where staff focused on the big players in health like the Global Fund and the U.S. President's Emergency Plan for AIDS Relief.[310] Two years later, in October 2012, Mr. Lunde shrugged off this hope, saying that there was "zero interest" in LSF 1.0 but at the same time expressing the possibility that LSF 2.0, which had recently been launched, would be the right product for that market.[311] The LSF 2.0 uses the same ultrafiltration membrane cartridge but is designed to sit on a table as opposed to hang on a wall and includes safe storage for filtered water (See Figure 12).

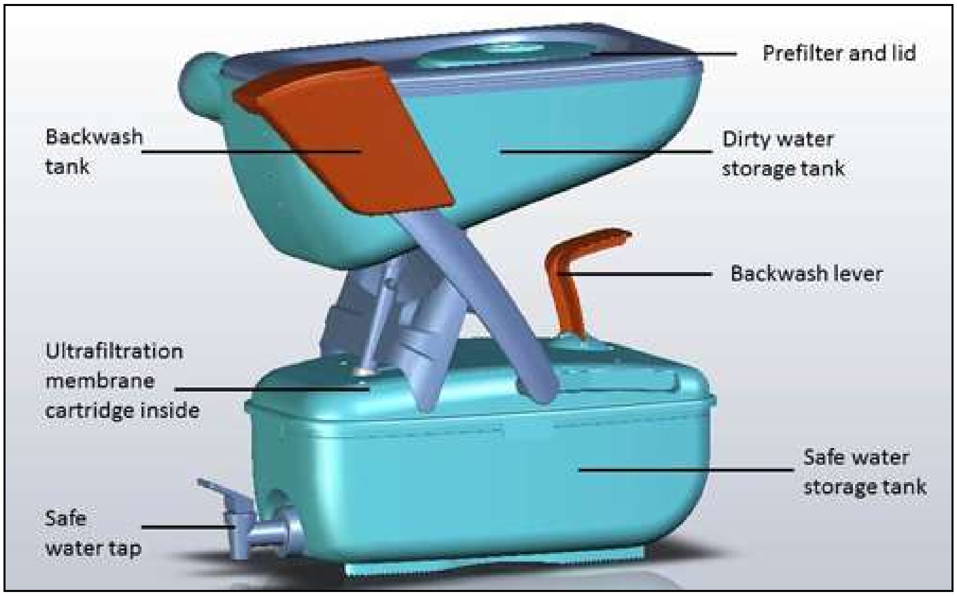

Figure 12. LifeStraw Family 2.0 Diagram[312]

Overall, he said, individual sales of LSF 1.0 had not taken off, with the exception of sales in the U.S. When asked to describe his target market, Mr. Lunde acknowledged that it was not the end user, saying, "We're not really relying on you [the end user] saying, 'I want that.'… And we don't believe you're going to spend $25, $35 before it's landed, for LSF 1.0 to buy it yourself… Nobody's going to spend [money] on it."[313] Instead, he said he targeted NGOs, potential donors, the WHO and country policymakers. This target market was confirmed by further discussion of recent sales of LSF 1.0 from the Accra office. At the time of the October 2012 interview, Mr. Lunde had recently concluded a "relatively big sale" of 20,000 filters to World Vision for implementation in Chad. Mr. Lunde also mentioned working toward a 200,000 filter implementation project with the Senegal River Basin Development Organization, which, to the best of my knowledge, never came to fruition.

Although these two projects differed in size by an order of magnitude, they both represent sales of a much greater scale than typical of Vestergaard's efforts in Ghana. For example, the company had previously sold smaller quantities to World Vision for implementation in four West African countries. When the Business Development Manager, Araba Sam Annan, joined the conversation, she told me about a couple of small-scale sales in Ghana that followed different models and required differing levels of involvement by Vestergaard. The first was the regular monthly sale of about 100 filters to the international NGO Global Brigades, which bought the filters from Vestergaard and then implemented them in the Central region. Their implementation model included a microcredit financing scheme, which wasn't intended to cover costs but rather was based on the concept that end user buy-in increased the sense of ownership.[314]

The second was a one-off sale to Addonai Community Church from the United States. The church had previously made donations for bed nets and had recently been encouraged by Vestergaard's U.S. office to donate money for filters. As a result, they donated $6,500 for 260 LSF 1.0 at $25 per filter (the price of a unit before shipping, as mentioned by Mr. Lunde previously). For the implementation of the 260 filters, Vestergaard decided to partner with the NGO Water in Africa through Everyday Responsiveness (WATER).[315] They had a number of reasons for partnering with WATER, including the extensive experience of the founder, Jim Niquette, who was the Ghana Country Director for the Carter Center's Guinea Worm Eradication Program from 2006 to 2011.[316] In this role, he was involved in the distribution of LifeStraw Guinea Worm filter,[317] which is a simple plastic tube with steel mesh inside to remove Guinea worm larvae[318], and was therefore familiar with Vestergaard and they with him. An additional, critical benefit to working with Mr. Niquette and WATER was the organization's tax exempt status in the United States, which was required for donations such as the one from Addonai Community Church.

With respect to location, all 260 filters were to be implemented in two communities in the Northern Region of Ghana. When asked what went into the decision to implement in the Northern Region, Ms. Annan explained that 5 regions had been chosen as the focus of HWTS efforts in Ghana, with respect to the overall efforts to scale up HWTS, and of these 5, the Northern Region ranked highest when it came to poverty, access to water and disease prevalence. In short, we can look at this as the need for HWTS interventions. But in addition to being a priority in terms of need, the Northern Region also scored well with respect to demand in the sense that all the major donors had offices in the region's capital, Tamale. For this reason, Ms. Annan said, "… politically, it might be good to get into the good books of the donors by having a small scale-up there."[319] Furthermore, the proximity of the implementation to Tamale would allow potential donors to see and verify the project by visiting it themselves. And so, although this was a one-time filter donation of a relatively small scale, Ms. Annan was enthusiastic about the opportunity to use this implementation as a springboard, saying that UNICEF was "keen" on the project and that Vestergaard could learn "the strengths, weaknesses, what needs to be done" and apply these lessons learned to future implementations. In this way, Vestergaard was leveraging a small donor and an NGO partner to engage with UNICEF, which is not only a lead stakeholder in HWTS policy development as a global actor (the co-host of the Network) and a local actor (the driving force behind Ghana's HWTS strategy development[320]) but also a key donor with respect to the purchase and implementation of HWTS products in Ghana.[321,322]

In addition to talking with Mr. Lunde and Ms. Annan about Vestergaard's sales efforts in Ghana and the surrounding region, I had the opportunity to observe the implementation of the 260 filters donated by Addonai Community Church. Most households in the community relied on a "dug out" (mud dam with a dug out area behind it that served as a reservoir) for their water; animals also had access to the reservoir. I observed women collecting water in large, metal bowls. The community consisted of many compounds, in which a husband lived with multiple wives and their children. It was the farming season, so most people were out working in the fields all day. For this project, WATER selected about a dozen people from the community to serve as a committee of community educators. This committee was tasked with a number of activities, including encouraging the community to maintain the water source and keep animals out, keep the community clean, hold meeting to discuss issues, and, of course educate the community on the LSF 1.0 and install the filters in households.

The implementation took place over 4 days - I was present for the first half of each of the first two days. The educators began filter installation the first evening, after a couple hours of demonstrations and training on the filter by Ms. Annan and once the people in the community had returned to their households after working in the fields. Because a family may consist of many households in one compound, multiple filters were sometimes distributed to a compound, with the general rule being one filter for compounds of less than 10 people, two for less than 25, and three for more than 25. On the second day, as a very conspicuous group, we visited 4 of the households that had received filters the previous evening. Most of the filters had been hung in a hard-to-access-place, and all of them had been hung outside, which Vestergaard encourages avoiding if possible. We spent the most time in one household, where water was being filtered into small, open basins set on top of larger, upside down basins, one of which was knocked over during our visit. Untreated water was stored in large, clay pots outside the home, next to the filters. While one woman was demonstrating use of the filter, another woman with a young child on her back came up to one of the clay pots, dipped a hollowed out gourd (and her hand) into it to collect water, gave the child on her back water to drink using the gourd, and then drank some herself. A boy of about 6 years also came and drank water from the pot, as did another mother. Observing this behavior - unsafe storage, consumption of untreated drinking water - showed that effective behavior change had not been achieved in the short distribution and implementation session.

Ms. Annan told me that regular education campaigns of 2-3 days were planned for the next four months, after which she hoped to have UNICEF and other potential donors come visit the pilot implementation. It was clear that much needed to be done before these visits, but unclear whether the motivation to educate and promote behavior change was to benefit the end users or to impress the potential donors in a courting process. From an observer's perspective, one of the key lessons learned from this pilot project was that such an implementation requires much more of Vestergaard than manufacturing and selling the product. The $25/filter donated by Addonai Community Church in the U.S. would come nowhere close to covering the true costs of the project, including program planning, transportation and implementation of the filters, education and behavior change communication, follow-up, and monitoring and evaluation.

From the discussion of the types of sales of LSF 1.0 and observation of the small scale pilot project, it seems unlikely that such activities would support Vestergaard's efforts around HWTS in Ghana. As mentioned previously, the company is well known for its insecticide treated bed nets, and Mr. Lunde summarized the challenge perfectly when lamenting the difference between the HWTS market and the bed net market, saying:

> "For a company like VF, it just doesn't fit our corporate culture because we're used to *millions* of nets. So when… we were traveling in Nigeria last week, and you go up and you talk to an NGO, and they're saying they're *considering* buying 200 for a trial. And you can just see his [Mr. Lunde's boss] eyes, like, 200, for a *trial*! So you know, you're 5 years down the road before you would even be beefing up something, which for us is what we're all about, as we claim. Not only about our business but we also claim that we're about big-scale interventions, because that was one of our motives for being commercial was that we wanted to go to scale quickly because we didn't want to be an NGO focusing on 200, 500. We wanted to go *big*. And we're struggling with this sector, where we actually think …we have the best filtration device in the *business* and we can't get it out!"[323]

In spite of these frustrations, Mr. Lunde and Ms. Annan held out hope that the LSF 2.0 would allow Vestergaard to succeed in the commercial market, working through direct sales representatives. But until this point, until they had built a market where people would buy their filters off the shelf, they said they would have to continue to rely on other buyers, whether that be the typical NGO or emerging interests such as cocoa producers looking to improve the health of their workers as a form of corporate social responsibility.[324] Mr. Lunde left Vestergaard in June 2013, and Vestergaard underwent a downsizing and closed a number of offices, including the Accra office. As mentioned previously, all of the company's activities in Africa are now run from the company's office in Kenya.[325]

3.5.2 Hydraid Biosand Water Filter

The second product of interest in exploring attempts at scale-up of HWTS in Ghana is the Hydraid Biosand Water Filter. As mentioned previously, Hydraid is an adaptation of the concrete biosand filter developed by Professor David Manz in the early 1990s. In 2002, individuals from Rotary International, led by Jim Bodenner, became interested in the Biosand filter, contributing to a pilot implementation, a Center for Disease Control and Prevention analysis of the technology, and a randomized, controlled trial. Bodenner also obtained permission from Professor Manz to produce a plastic version of the filter. In 2006, the production license was given to International Aid, a non-profit, faith-based organization, and Bodenner became the Director of Water Initiatives for the organization. In 2008, International Aid partnered with Cascade Engineering to produce Hydraid,[326] and the Dow Chemical Company donated enough plastic resin to produce 300,000 filter bodies.[327] In August 2009, financial problems forced International Aid to suspend all of its international programs. Before shutting down, International Aid had implemented about 25,000 filters in Honduras, the Dominican Republic and Ghana.

Following International Aid's cessation of Hydraid activities, Cascade Engineering made a deal with the organization to obtain rights to the filter and also got a license from Professor Manz. Then, in January 2010, Cascade Engineering announced that it was partnering with Windquest Group, a Michigan-based private investment fund, to "ramp up" Hydraid production and distribution, aiming to reach its 250,000 filters per year production capacity.[328] On July 31, 2015, Triple Quest, the join venture between Cascade Engineering and Windquest Group, announced that NativeEnergy, a company with which it had partnered for carbon financing projects, had acquired the rights to Hydraid. Cascade Engineering would continue to manufacture the filter; Triple Quest would cease its operations; and Native Energy would distribute the filters. At the time of this handover, TripleQuest said that there were more than 75,000 Hydraid filters in 46 countries. One can estimate, then, that from January 2010 to July 2015, TripleQuest distributed approximately 50,000 filters, nowhere near its goal of 250,000 filters per year. NativeEnergy's activities around Hydraid are unclear, as the Hydraid website now redirects you to NativeEnergy's home site. The company's webpage on its Clean Water Campaign (implementation of Hydraid filters for carbon credits) only has information on projects up to 2013. Hydraid's future, then, is unclear.

At the time of my fieldwork, Hydraid was being produced by Cascade Engineering and distributed by Triple Quest; the non-profit Safe Water Team, founded by Rotary Club member Jim Bodenner, supported distribution and implementation. Specific to Ghana, in 2011, the Safe Water Team set up a distribution center in greater Accra.[329,330] In 2012, another venture centered on Hydraid implementation in Ghana was initiated; Ghanapreneurs was founded by Beth Devroy, formerly of Amway, as "a social entrepreneurial business that offers the Hydraid bio-sand water filtration system in Ghana through local entrepreneurs."[331] Together, the efforts of the Safe Water Team and Ghanapreneurs constituted Hydraid implementation activities in Ghana. I'll explore these efforts here.

In January 2010, the Safe Water Team had about 1600 Hydraid filters waiting in a warehouse in Ghana, and Jim Bodenner was looking for someone to act as a non-profit distributor, with a focus on selling the filters to entrepreneurs, micro businesses, NGOs and churches at full-cost recovery[332], which came to about US$115 per filter.[333] As Mr. Bodenner put it, "Triple Quest is trying to figure out how to create the whole micro-business end of things… the Safe Water Team is focused on the humanitarian implementation of filters." As of March 2011, Bodenner, had identified Pastor Josephus Hallie through a New York pastor as the likely person to run the distribution center in Ghana.

While in Ghana in the last quarter of 2012, I had the opportunity to speak with Pastor Hallie to learn more about his efforts to run the Safe Water Team's distribution center. By that time, the Hydraid filters in the distribution center were outdated models, as the design of the filter had since been updated to account for leaking and breakage at the base of the filter's stand pipe. Pastor Hallie's role was unpaid, but he had recently founded a new church in the Northern Region, where Hydraid implementation activities were largely focused, and saw this as an opportunity: "I thought… that would be good because if we want to go into villages and implement these filters, that would give us the opportunity to preach the Gospel to people at the same time." As mentioned earlier, the person who had connected Pastor Hallie to Jim Bodenner was also a pastor, Pastor Jerry based in New York City, and because of this connection, many of the filters implemented by Pastor Hallie were funded by individuals in Pastor Jerry's church. Specifically, Pastor Hallie was working to implement filters in all 110 households of a community in the Northern Region named Bagliga. Of the first 60 filters to be implemented, 20 were paid for by Pastor Jerry's church in the U.S.

As to how Pastor Jerry solicited donations for the filters, Pastor Hallie told me that he would go to the community to take stock of the water and sanitation challenges, taking pictures of dirty water and unsanitary conditions as well as sick children, and then send these pictures and the accompanying information to Pastor Jerry to use when looking for donors to fund the filters and their implementation. The money donated was intended to cover the cost of not only the filter but also the transportation and installation. Unfortunately, Pastor Hallie had found that it was quite difficult to anticipate all of the costs of transportation and installation: "They charged me almost 5 cedi for one of them, just the filters, because of the extra care that I had said I wanted… not to mention the sand and the stones… I had to transport them from here [Tema] to Accra. At a cost, transferred them from Accra to Tamale. At a cost, transferred them from Tamale to the village. At a cost. And some of this cost I didn't even consider. I had only considered the transportation… that would take us from Accra to Tamale." Because of such unanticipated costs, Pastor Hallie had to contribute his own money on certain occasions, in addition to his own time.

Once the filters were in the village, the Chief decided on the order in which filters were distributed. Pastor Hallie expressed regret that this meant that those who received the filters first weren't those who needed it the most, such as children and the elderly, but thought it not his place to intervene. With respect to training on filter use, Pastor Hallie said that he educated the recipients in a group before starting implementation and then educated individual households when implementing each filter in a home. He acknowledged the limitations of such education and training in achieving behavior change and household water treatment uptake, having observed that improper collection and storage of water had continued after the training and implementation, as had consumption of untreated water. Community members of Bagliga were not required to pay for the filters, but Pastor Hallie had asked them to commit to building public toilets. As of the time of our conversation, more than half of the 110 filters had been implemented, but the construction of the toilets had not yet been initiated. Pastor Hallie planned to require that they start construction before the remaining filters were implemented.

The implementation in Bagliga was the main activity that Pastor Hallie had overseen. He spoke of 30 filters sold to a Baptist missionary group in Togo and of a few implemented in southern Ghana. Although a few people had expressed interest, there had been no direct sales. Pastor Hallie explained that "the money is too much" (200 Ghana cedis per filter), even for those who work and, he feels, have the money. Of the approximately 1400 filters at the distribution center when Pastor Hallie took over, there remained 1264 filter bodies, although there were not components for 1264 complete filters.[334] Based on the number of filters remaining, approximately 450 filters had been implemented (although implementation is not certain) since 2010, or about 10-20 filters per month. As Jim Bodenner said, the focus of the Safe Water Team was humanitarian implementation, not business, but given the set up - with Pastor Hallie volunteering his time and sometimes even his money - and the low rate of implementation, such an incremental, inconsistent means of funding and implementing was not sustainable. Given that Pastor Hallie had encountered little to no demand from potential middle-income consumers, commercial sales of the filters was highly unlikely and could not be relied upon to generate revenue.

At the same time that Pastor Hallie was managing the Safe Water Team distribution center and waiting for donations from the U.S. to fund filter implementation, Beth Devroy was pursuing a for-profit sales model for Hydraid implementation in Ghana. Although Pastor Hallie had experienced a lack of demand from potential middle-income buyers, Ms. Devroy established Ghanapreneurs in 2012 intent on starting and supporting micro-franchises that targeted filter sales to this market. Ms. Devroy's decision to pursue direct sales of the filter to consumers through micro-franchises run by individual entrepreneurs was based on over 20 years' experience working for the multi-level marketing company Amway. This experience included, most recently, helping to start up an Amway spin-off in Ghana - Bon Vi! - through which local women sold consumable products like soap and lotion directly to individuals, as opposed to the distribution model of selling to shops and vendors. [335]

Ms. Devroy hoped to set up a similar process within Ghanapreneurs that focused on direct sales to middle income consumers for whom the filter price (originally set at 170 Ghana cedi, although it increased to 200 Ghana cedi) would not be insurmountable. Although she thought the sticker price was reasonable for her target market, she anticipated that selling a durable good as opposed to a consumable one would prove challenging at first and would require adapting the business model and convincing consumers of Hydraid's value. In addition to ability to pay, she also cited accessibility as a reason to focus on middle-income consumers; she was quick to acknowledge that Ghanapreneurs would not be able to reach remote villages, saying that NGOs are better able to serve such areas. She did, however, hope to eventually incorporate corporate social responsibility (CSR) into Ghanapreneurs' activities, with corporate foundations like Unilever and Nestle sponsoring implementations for lower income households.[336]

As for the short-term plan, when I first spoke to Ms. Devroy by phone in June 2012, she planned to pilot the micro-franchise sales model in July with a select group of entrepreneurs, regroup and share lessons learned in August, and go back out in September for a big sales push.[337] This plan was delayed for a couple of reasons. First, the entrepreneurs were struggling to understand the micro-franchise model and needed more training. Second, the filters that Ms. Devroy had purchased from the Safe Water Team distribution center for the pilot had been found to leak after installation. As Pastor Hallie pointed out, the design of the older Hydraid version often leaked because of the standpipe's connection to the filter body. Ms. Devroy deemed this unacceptable, given that it would tarnish the filter's (and Ghanapreneurs') reputation. To solve this problem, she ordered a container (2250 units) of new Hydraid filters from TripleQuest. As of the end of July, these filters were in port waiting to be released, pushing plans back by a couple months.[338]

As part of these plans, Ms. Devroy anticipated having 8 to 12 entrepreneurs active by September. A significant hurdle to achieving this goal would be the upfront investment she required of those interested - a US$75 application fee, which covered a Hydraid unit, training and some marketing materials.[339] When I joined Ms. Devroy and her assistant Pius Abuntori for a market storm in the ministries area of Accra at the beginning of September, two entrepreneurs had paid the application fee to become micro-franchise business owners (MBOs), and three others were interested. This was after a series of recruitment attempts. As anticipated, the application fee was considered a barrier by many who had initially expressed interest, but Ms. Devroy and Mr. Abuntori continued to emphasize the importance of financial commitment.[340]

At the market storm, Ms. Devroy and Mr. Abuntori were joined by the two MBOs and one woman interested in becoming an MBO. The intent of the exercise was to give the MBOs experience in marketing the filter and to increase awareness of the filter among the ministries' population - largely young professionals working within the Ghanaian government. Over 2.5 hours, at least 200 people stopped by, with some simply taking a flier and others staying longer to see the filter work and ask questions. Altogether, the five of them collected contact information from about 75 people, 4 of whom told Beth they planned to buy the filter. Follow up would be key, as closing the deal had proven challenging thus far. At the time of the market storm, Ghanapreneurs had installed 9 filters, and a multi-filter implementation was planned for tomorrow, when 8 filters would be installed at a school. Each of these filters had been paid for by individual alumni who wanted to do something to support their school.[341] To my knowledge, none of the 9 filters installed previously was the result of a direct sale.

When I next spoke to Ms. Devroy and her husband, Dave, the technical lead within Ghanapreneurs, in November, they had made two shifts with respect to their operations. The first was a shift in the geographical focus of their direct sales efforts from the Ministries area in Accra to the Ashaiman area outside of Tema. This move brought their marketing activities much closer to their base of operations - the Devroy's home - while also targeting a middle-class, educated population. The target for November was 100 installations in the Ashaiman Area. Although they continued to pursue direct sales, however, Ghanapreneurs had also shifted most of its focus to CSR. Ms. Devroy cited several challenges that led to this shift:

- Recruiting qualified, professional MBOs

- Achieving a price range acceptable to the consumer while still profitable to the MBOs
- Marketing a durable product, as compared to a consumable product

The hope was that CSR would be the point of entry into lower-income communities and would subsidize sales.

With respect to continued marketing efforts for direct sales, Ms. Devroy asserted that there are still “early adopters” who would buy the filters. To increase demand in the rest of the population, Ghanapreneurs planned to implement filters in clinics, pharmacies and hospitals - locations where the filters would be visible and used by those who “the masses” trust and respect. They also planned to continue selling filters to individuals who wanted them to be implemented in their home village or school, such as the 8 filter implementation mentioned previously.[342] I did not get official numbers from Ms. Devroy regarding sales and implementations, but online postings document a total of 12 filters donated and 5 filters purchased by households between September 2012 and February 2013.[343] Although one cannot assume these online postings represent all sales and implementation activities, one may infer that such activities were likely more on the order of 10 filters per month as compared to Ms. Devroy’s 100 filter target for November.

There was, however, one development that would have dwarfed Ghanapreneurs’ activities thus far: in February 2013, Ghanapreneurs posted that it was awaiting certification by the Gold Standard Foundation, which signaled a move into carbon credits as a means of funding filter implementation (not unlike Vestergaard’s Carbon for Water campaign). This announcement was confirmed by Native Energy, a carbon offsets company, which posted a description of the Ghana Clean Water Project on its website.

The project was to be a collaboration between Native Energy, Triple Quest and Ghanapreneurs. Approximately 1,700 filters were to be implemented in home and schools in Greater Accra with a projected reduction of 70,000 metric tons of carbon dioxide. In addition to installation, implementation would include training, and support on maintenance and use would continue throughout the 10 year project period.[344] Since these postings, however, no further information has been provided on the Ghana Clean Water Project. The last online post by Ghanapreneurs was in September of 2013, and no project updates have been posted by Native Energy on the project's website.

3.5.3 AfriClay Filter

The third and final product we'll look at here - the AfriClay filter - has been present the longest and has been implemented at the greatest scale in Ghana. Globally, the champion of ceramic pot filters was Ron Rivera, who was drawn to the technology developed by Fernando Mazariegos. Although Mr. Rivera's organization Potters for Peace was originally focused on local production of ceramic products to be sold for a profit in the US, with the money made then returned to the local community, he quickly shifted to a focus on the local production and sale of ceramic pot filters.[345] The first filter factory was built in Managua, Nicaragua in 2002.[346] In 2003, it was Mr. Rivera who worked with the local ceramics manufacturer Peter Tamakloe in Ghana to build a kiln and filter press and start making ceramic pot filters in the country.[347]

As of 2012, there were two factories producing ceramic pot filters in Ghana: Ceramica Tamakloe and Pure Home Water (PHW). PHW was founded by Susan Murcott, a Senior Lecturer in Civil and Environmental Engineering at Massachusetts

Institute of Technology (MIT). Ms. Murcott's interest in the ceramic pot filter began in the early 2000s. The first independent studies of the ceramic pot filter were conducted at MIT, and Ms. Murcott's students worked with the original disseminators of the filters - Ron Rivera and Potters for Peace. Following these activities, Ms. Murcott founded PHW in 2005 as a social enterprise with two goals: (1) to provide WASH services to people in Ghana, with a focus on Northern Ghana, which faces particularly significant WASH challenges; and (2) to become a "financially and locally-self-sustaining" organization.[348] These two goals seem to be directly tied to the initial funding for PHW: a 2 year grant from the Hilton Foundation "to look at the viability and sustainability of setting up a business to disseminate household water treatment in Northern Ghana."[349] Although PHW now focuses its efforts on a single product, the AfriClay filter, the original intent was for the organization to provide a suite of HWTS options.[350]

This original intent led Ms. Murcott and her students to look into ceramic candle filters that were produced in Kumasi, but they soon found that the treatment these filters provided was unreliable. Outside of the ceramic candle filters and the ceramic pot filters, they didn't find any other products on the market in Ghana, and so they decided to focus on the ceramic pot filter. Originally, PHW purchased the filters from Ceramic Tamakloe in Tema, in the Greater Accra Region.[351] Ceramica Tamakloe was the sole producer of ceramic pot filters in Ghana at the time.[352] In the first five fiscal years, from 2005 to 2010, PHW distributed 15,695 filters. The majority of filters sales (about 75%) in these first five years were to UNICEF for distribution as a part of emergency response efforts for the floods in 2007-2008 (7,700 filters) and for the Guinea worm outbreak in 2008-2009 (4,000 filters).[353,354] Later in 2010, UNICEF and the Ghanaian Ministry of Local

Government and Rural Development (MLGRD) purchased and distributed another several thousand filters through PHW.[355] Based on this information, the majority of the filters sold and distributed during this time were provided in bulk, as opposed to sold commercially, directly to consumers.

As time passed, PHW became more interested in being involved in not only filter distribution but also filter production. This was based on a desire for better quality control and more reliable supply chain as well as an interest in experimenting with changes in filter design - specifically, making the filters bigger to better meet the needs of the larger average family size in Northern Ghana. [356]And so, in 2010, PHW broke the ground for its own filter factory outside of Tamale, in the Northern Region, working with Manny Hernandez of Potters for Peace to set up the production facilities[357] (Ron Rivera died of malaria in Nigeria in 2008 while building the 30th filter factory).[358] Ms. Murcott continued to involve MIT students in research on different aspects of ceramic filter design and production to inform the construction and operation of the PHW factory.[359] Although some filter factories have been built with US$20,000, the PHW factory would end up costing between US$150,000 and $200,000. The funding for construction came largely from grants from individuals in the U.S. and from the Gerard Health Foundation.[360] In January 2012, the PHW factory started commercial production of the filters and was one of 36 factories in 18 countries at that time.[361,362] As a result, PHW's AfriClay filter became a competitor of Ceramica Tamakloe Filtron Water Filter.

When I spoke to Mr. Tamakloe in October 2012, he expressed uncertainty as to whether he would continue to actively produce and sell ceramic pot filters given that PHW had started producing its own filters in Tamale:

> "All my business comes from the North… If they are doing it [filter production] in the North, then UNICEF will buy from them… So if they are doing it there, then what business do I have here? And so all that puts me off and tells me, 'Hey, forget about this. Let me do what brings me money.'"

Large purchases from UNICEF, his biggest buyer over the years, had previously been what excited and energized him and encouraged him to continue to produce the filters. Outside of a sale of about 800 filters to an NGO in Nigeria earlier in 2012, Mr. Tamakloe told me that he now sold less than 100 filters per month, which was not enough to sustain his business.[363]

Those who did buy the filters were from the middle class, for the most part, and this middle class was growing, which could potentially lead to increased demand. But his current sales numbers did not reflect this potential and gave him little leverage with suppliers; for example, when ordering plastic buckets for the filter housing and storage, the supplier would not be interested in an order for 200, as it was nowhere close to the minimum order of 2000. As a result of little to no demand for ceramic pot filters, Mr. Tamakloe had shifted the majority of his resources to producing and selling terra-cotta tiles for roofs, which were in high demand. Of the demand for filters, he said, "It's not the kind of thing that can sustain me on a daily basis."[364]

When I asked Mr. Tamakloe what he had learned about generating demand and sustaining filter production as a business, he pointed to two key activities that had proven most challenging to him: marketing and distribution. He spoke of his failed marketing efforts, which included putting $10,000 into running advertisements on television, money that he mostly lost because these advertisements did not generate enough orders to cover the costs. But lack of distribution was tied to - and perhaps a main cause of - his marketing failures:

> "Looking back, we didn't get the orders because we didn't have the strength of CocaCola. If you advertise CocalCola, it is present in every nook and cranny of this country. If I want to sell filters, I need to move filters from my hands into every district, every village. So as they see it on TV, they pick it [up] next door. I don't have that capacity."

Even in instances in which Mr. Tamakloe successfully marketed and distributed filters, he then encountered another obstacle: trying to maintain sales of a durable product after the initial purchase. He contrasted ceramic pot filters with milk, saying that with milk, you drink it and it's gone, so you have to buy more milk the next time you want some. On the other hand, when people bought filters, they were still using their filters three or four years later. So, generating initial demand was not sufficient to sustain filter sales.

I spoke further on the challenges of generating demand for the filters with Mary Kay Jackson, the Managing Director of PHW, in November 2012. She informed me of a willingness to pay study that Innovations for Poverty Action had performed on ceramic pot filters in Northern Ghana.[365] This study found that the mean willingness to pay for a filter was GHC5 (~US$2.50).[366] The price for a PHW filter at the time of the study was GHC50 (~US$25) and for a Ceramica Tamakloe filter was GHC35 (~US$17.50), putting willingness to pay for a filter on the order of 10% of the sales price.[367,368] In November 2012, PHW was finishing the construction of a new, larger kiln that, once online, would be able to fire 100 pots at a time as compared to their current kiln's 32 filter capacity. This would lead to an increase from 250 filters produced per month to 1000 filters but would not bring the cost to produce down low enough to match the sales price with the willingness to pay.[369] In comparison, Ceramica Tamakloe claimed a production capacity of over 3,000 filters per month.[370] And so, willingness to pay would continue to be an obstacle to PHW's goal of becoming financially sustainable.

Ms. Jackson felt that another, related, obstacle to becoming a sustainable business was free distribution of filters through UNICEF, as her experience led her to believe that it conflicted directly with direct sales of the filters. At the same time, she acknowledged that GHC50 was too much for a rural household to pay. As a result, PHW had started looking into other options in order to reach this target population while at the same time covering PHW's expenses. One avenue they were exploring was microfinance; another was sales to higher income, urban populations, such as those in Accra and Kumasi. At the time, PHW was selling a couple of hundred filters a year to higher income, urban consumers without heavily marketing filters to this population. To build on this latent demand, PHW had begun developing a ceramic pot filter that would have greater appeal and aspirational value in the urban market. They hoped to then sell enough of these filters at enough of a markup to subsidize sales in rural villages. In the meantime, though, PHW would continue to rely on sales to UNICEF, INGOs like Oxfam and Rotary International, and local NGOs like the Community Life Improvement Programme.[371] Such sales would likely entail free distribution of the filters to all households in a specific community, as was the case for a 1,100-filter distribution funded by UNICEF that I observed in November 2012, as opposed to the consumer choosing the product in the case of direct sales.

The November 2012 filter distribution took place in a rural area outside of Tamale. The goal of the implementation was to install a filter in every compound (a group of homes shared by a man and his wives) in a village before moving on to the next village. The target during the implementation campaign was 100 filters per day, in two groups of 50 women, if this many women could be found who were willing to participate. About 30 minutes were spent on the set-up, use and maintenance of the filter before women were given a filter and broken up into groups of 10-12. These smaller groups then went to one of the group members' compounds to go through the process of cleaning and putting together the filters and then one by one going to their compounds with the educator to install the filter in a safe place in their home. Poorer families or those with children, elderly, or people living with HIV were not specifically targeted or sought out.

When I spoke with Ms. Jackson in August 2013, I was able to follow up on PHW's increased production capacity, recent implementations, and the development of their higher end product for urban, middle class consumers. The new kiln had successfully quadrupled the factory's production capacity, although normal operations put production at about 720 filters per month, with an increase to 1,000 only if necessary, as it put a lot of stress on the quality testing employees. The ability to produce more filters came at a good time, as Ms. Jackson anticipated that PHW would sell about 5,000 filters that year. A 1,500 filter Rotary Club project had contributed significantly to this number. Ms. Jackson's reflections on this project tied back to our discussion the previous year about willingness to pay and the perceived negative impact of free distributions on willingness to pay. She told me:

> "Originally, they were supposed to be sold at GHC5, about US$3 at the time… We'd gone to villages and done preliminary surveys, and everyone said, 'Oh, yeah. This is great. We'd love to buy them.' But when we went back to actually do it, there was resistance. People were saying, 'We'll just wait for UNICEF to do them for free.' So we ended up not collecting the GHC5 from them. We needed to go ahead with the project and get it done instead of wait and drag it out."[372]

This wasn't the first time that PHW had encountered such pushback on paying for filters, and Ms. Jackson wasn't the only person from whom I'd heard a belief that free distribution negatively affected other means of implementing filters. It was, however, the first time I had heard a specific, albeit anecdotal, example as opposed to a general statement.[373]

Several questions remained for me after hearing this anecdote, although the answers to them would not affect the outcome of the project itself but rather be general reflections on HWTS sector activities, with this project as a specific example. What was the intent of collecting payment for the filters: creating a sense of ownership for the filters among households, achieving partial cost recovery, or both? Does (lack of) willingness to pay reflect (lack of) demand, and how does it affect uptake? Was the original plan to only sell filters to households in which there was a demand and willingness to pay for the filter and was the actual result that filters were distributed to every household, regardless of demand? If highly subsidized, direct sales prove impossible as in this case, is there a middle ground between that and blanket, free distribution?

Direct sales to the urban middle class in Ghana had proven more successful than the Rotary Club project's attempt to sell filters to rural, lower income people, although such sales only represented about 20% of PHW's filter sales. Ms. Jackson's long-term vision of PHW as a business would rely upon direct sales making up 75 to 80% of sales. At this proportion, direct sales would drive and sustain the business, enabling PHW to continue to occasionally do humanitarian projects with donors but freeing the organization from depending on inconsistent donor funding. At the current rate of sales, PHW was close to the break-even point. Increasing direct sales would help the organization make progress toward its goal of being financially self-sustaining.

Two activities would help move PHW in this direction: producing a higher-end filter and increasing marketing efforts. As of August 2013, the higher end filter was still in product development, and Ms. Jackson anticipated that it would be rolled out in early 2014. The urban, middle class target market would overlap significantly with the population currently buying filters through direct sales but would expand sales from being largely focused around Tamale to including other urban centers like Accra, Kumasi and Sunyani. At the time of our conversation, most of PHW's marketing was through word of mouth, although those who purchased the filter often learned about PHW and its filters on its website. Ms. Jackson planned to work on a more focused marketing campaign for the higher end product that fall in the aforementioned cities. These two activities would be focused on increasing direct sales, but PHW still had a long way to go from 20% to 75-80% of sales.

In addition to financial sustainability, PHW's desire to increase direct sales was driven by other perceived benefits around filter uptake and PHW's interaction with filter users. Ms. Jackson reflected on some differences between direct sales and community-based implementation that she'd observed. With direct sales, she said, PHW was, simply put, dealing with the user directly. Their desire for a filter is what led them to come in to buy one, and this desire translated to a higher uptake of the product. Furthermore, it increased the chances that if the filter broke, they would come in to get replacement parts. On PHW's side, they aimed to follow up with buyers when it was time to replace filter parts, although they weren't yet 100% consistent on this follow-up. In a community-based implementation, the project benefits if the community as a whole embraces it and there's resulting peer pressure and support around filter use. On the other hand, her perception was that lack of (financial) investment in the filter by households could lead to misuse of the filters - such as using the filters for food storage instead of water filtration - even in the presence of community support and accountability. Furthermore, follow up training and support was dependent on funding for such activities being included in the project budget.[374]

Ms. Jackson's observations and reflections mirrored those shared by many in the HWTS sector, which are the basis for continued support of commercialization as a means of scale-up. Unfortunately, based on PHW's experience and plans moving forward, the perceived benefits of direct sales would only apply to the urban, middle class consumers the organization planned to target with its marketing and higher end product, while poor, rural communities would likely continue to be recipients of blanket implementations of free filters. As a result, the organization's goal of becoming financially self-sustaining seemed to be in conflict with its other goal of meeting the WASH needs in Northern Ghana, where some of the greatest WASH challenges in the country existed in poor, rural communities.

3.6 Conclusion

In 2010, UNICEF hired a consultant, Marion Kyomuhendo, to assess the status of HWTS in Ghana.[375] This assessment found that HWTS was a "relatively new phenomenon in Ghana."[376] According to the report, at the time of the assessment, boiling was the most common form of household water treatment in Ghana. Other HWTS efforts were ongoing, mostly at the pilot stage, and some products that had been promoted were then not consistently supported and continued. In the report, Ms. Kyomuhendo concluded:

> "…chances of promoting viable HWTS programs are promising in Ghana. Therefore, HWTS should be piloted using a business approach. The private sector if involved in a timely manner can provide delivery systems of safe water and sales of HWTS options. Apart from emergencies, delivery of HWTS products should be assigned to the private sector including large companies or small informal enterprises."[377]

While she promoted the commercialization of HWTS, Ms. Kyomuhendo also identified several challenges to achieving this goal. Most significantly, she discussed the difficulty of achieving full cost recovery when selling products to rural households, especially given the practice of free or highly-subsidized distribution of HWTS products.[378] And indeed, PHW encountered such difficulties with respect to trying to sell its filters or even recover some costs. Similarly, Ghanapreneurs was largely unsuccessful in selling Hydraid filters, even though its entrepreneurs were targeting middle-income, urban households, not poor, rural households. And Vestergaard had fully abandoned its hopes of direct sales to consumers.

In 2015, the WHO hired a consultant, Roshini George, to perform a rapid market assessment of HWTS in Africa, South-East Asia and the Western Pacific. This assessment included field visits to Ghana, Ethiopia and Vietnam. The report from the assessment did not go into detail on Ghana-specific findings. More generally, in Sub-Saharan Africa, chlorination was found to be the most common form of treatment besides boiling, and the use of chlorine for household water treatment was often in the context of emergencies or disease outbreaks. Although imported and locally produced filters were available, they were not widely used. In instances in which sustained uptake was achieved (typically chlorination), this success was credited to continued social marketing or ongoing NGO interventions. The report concluded:

> "The three main priorities to support scaling up of quality assured HWT products are: stronger and more comprehensive regulations; increasing availability of quality HWT products; and broader enabling environment support [sic] including use of targeted market approaches, smart subsidies and consumer understanding and behavior change."[379]

Applying the broader Sub-Saharan Africa findings to Ghana, five years later, little progress appeared to have been made toward HWTS scale-up, particularly with regards to moving beyond coverage to achieve uptake as well. While the report credited continued, non-profit efforts (e.g. social marketing and NGO interventions) when sustained use was achieved, not commercial activities, it included market approaches among the priorities, just as the 2010 report emphasized a business approach. And so, in spite of the fact that true scale has not been achieved over the past 5 years of emphasis on commercial approaches, the sector – and notably, the sector-leading WHO – continues to put commercialization forth as a means to achieve scale-up.

In the Ghana case studies, PHW had, over almost a decade, gotten direct sales up to 20% of filter sales, with these efforts and plans for increased direct sales largely focused on an urban, middle class. Ghanapreneurs focused its efforts on the urban, middle class, but was unsuccessful. Similarly, Mr. Tamakloe of Ceramica Tamakloe could not achieve a level of sales that would sustain his business, although he expressed some interest in the growing middle class and potential sales to these consumers. In short, the efforts toward commercialization of HWTS in Ghana that I observed over four years of fieldwork were focused on selling products to the urban, middle class. When considering the argument for HWTS as an interim measure while working toward the long-term goal of piped treated water, the often-discussed target populations are the rural poor and other vulnerable populations. Conversely, the urban middle class seems positioned to be the population most likely to be reached by centrally treated, piped water, in an ideal world.

But Ghana is not an ideal world. Only 8.4% of the urban population report using piped water into their dwelling as their source of drinking water. Compare this to the 38% that report using sachet water,[380][o] and it's clear that one of two scenarios, or some combination of the two, is taking place: (1) Ghana Water Company Limited (GWCL) is producing sufficient, treated water to serve a higher percentage of urban residents, but residents do not trust the quality of the water and therefore purchase sachet water for drinking; or (2) GWCL is not producing sufficient, treated water, and therefore residents must seek out other drinking water sources. What is clear either way is that sachet water is preferred over HWTS, given that only 5.3% of urban households use an appropriate treatment method.[381]

With respect to the state of urban water supply in Accra, the Chief Water Quality Manager for GWCL spoke with me frankly about the risks of contamination of treated water in Accra's distribution system. Water quality at the tap can be unreliable in Accra due to rationing of water that can lead to negative pressure in the pipes and incursion of contamination through cracked pipes.[382] Rationing means that there is insufficient water to meet the needs of those connected to the piped system, and a compromised distribution system means that the water isn't guaranteed to be safe upon its arrival at the tap.

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[o] A sachet is a 500mL sealed, plastic bag filled with drinking water and sold commercially

Furthermore, GWCL covers the cost of operations with money collected from those with piped connections, but funding for development of new systems (and presumably replacement of old, failing systems) must be sought out by the government, often through loans from development partners, making such increased and improved service uncertain. Do efforts to scale-up HWTS among the urban middle class create the potential for a diversion of government and donor resources away from the stated long-term goal of centrally treated, piped water? Does this not imply that the public sector in Ghana has been deemed unable to provide reliable, treated, piped water to its citizens?

If so, then the commercialization of HWTS is a shift of responsibility for safe water provision from the government to the end user. And in fact, when considering the arguments for HWTS and its commercialization, parallels quickly emerge between these efforts and the theories of neoliberalism. In identifying and exploring these parallels, I am not arguing that HWTS is neoliberalism at work but rather pointing out how HWTS fits in well with the neoliberal approach and arguing that these parallels are worth exploring further. My intent is not to vilify or blame the actors involved but rather to highlight the need to inform ourselves as a sector of the context in which HWTS efforts are taking place and the history of development that has certainly influenced and continues to influence these efforts. Furthermore, we need to think about where ideas come from and how we decide what strategy to pursue when faced with a complex problem such as safe water. Within this, we need to manage our assumptions – the key one here being that the market will succeed in carrying HWTS forward.

Before discussing these parallels, let us first establish a very basic description of neoliberalism. According to David Harvey, the theory of neoliberalism “holds that social good will be maximized by maximizing the reach and frequency of market transactions, and its seeks to bring all human action into the domain of the market."[383] Further, it emphasizes dignity and individual freedom, and specifically the freedom of consumers to choose within the market. With this freedom and dignity also comes an individual's responsibility and accountability for his/her own actions, including ensuring his/her wellbeing.[384] Practically speaking, the enactment of neoliberal values has, among other things, led to the shifting of responsibility for service provision from the public sector to the private sector.

What, then, are the parallels between the support of HWTS and its commercialization and some of the key tenets of neoliberalism? First, there is the shifting of responsibility for service provision from the public sector to the private sector. In the case of HWTS, this shift isn't a perfectly clean one, as it entails going from the provision of treated, piped water to the production of the means to treat one's own water (through HWTS products), but essentially, it is the privatization of a public service. This shift also moves the burden of responsibility for safe water provision from the government to the end user. Second, as with neoliberalism, which emphasizes markets as a way of giving "choice and voice"[385] to users, proponents of HWTS and its commercialization emphasize the shift of end users from being recipients of aid to being consumers who can make their own choices and provide safe water for their families.[386]As quickly as these simply parallels emerge so, too, do the challenges of and contradictions within efforts to achieve scale-up of HWTS.

With respect to the move from public to private sector, one of the arguments for this is the government's incapacity to provide safe water to its citizens. Unfortunately, with the reduction of capacity required for safe water provision through HWTS comes the increase in capacity requirements for other activities of the state such as regulating the private sector (which we'll see is a challenge for the Ghanaian government in the following chapter).[387] Further, as mentioned above, going from treated, piped water (or at least the long-term goal of achieving this) to HWTS also shifts the burden of responsibility from the government to the end user. Unfortunately, in the case of HWTS, the target end users are vulnerable populations - the poorest of the poor, children, the elderly, people living with HIV/AIDS. These vulnerable populations are the least likely to be able to shoulder this burden and certainly are not equipped with all of the resources to do so, particularly when it comes to the first step – buying a HWTS product – if commercialization were achieved. Hence the tendency for producers in Ghana to focus on the urban middle class as potential consumers when trying to commercialize and also the finding that both P&G and Vestergaard had to rely on non-commercial means to reach vulnerable populations.

In order to achieve scale (although uptake remains uncertain) and continue to produce and distribute the P&G Purifier of Water, the successful, global consumer products company Procter and Gamble had to acknowledge that these efforts would not make any profit and turn them into a corporate social responsibility endeavor. In order to reach 91% of the population in Western Kenya without access to safe water, Vestergaard had to invest $30 million, engage in a novel-to-HWTS carbon credit scheme, and commit extensive resources for a projected 10-year program. Neither of these efforts involved direct sales nor did they achieve the oft-stated objective of commercialization of HWTS - consumer choice. They did, however, achieve a scale far greater than most HWTS efforts, relatively rapidly. As with any HWTS intervention, ongoing follow-up and support as well as distribution and supply chain management will be required to achieve sustained uptake.

Achieving true scale-up - coverage and uptake - of HWTS in Ghana will require no less. There are an estimated 3.3 million people in Ghana who lack access to safe drinking water. Of this population, 17% report treating their drinking water, meaning approximately 2.7 million are still in need of HWTS solutions. Given the mean household size in rural areas in Ghana is 4.3, then this is about 640,000 households.[388] Assuming $50 per HWTS product to cover not only product cost (about $25) but also the costs of distribution and implementation, this would come to approximately $32 million, comparable to the $30 million Vestergaard invested in its Carbon for Water campaign. As Mr. Tamakloe said, "So you can take the filters and go and give it to everybody in the country? Think about it. There's no reason you can't. Think about it. Raise the money."[389]

In sum, if HWTS is to continue to be pursued in Ghana as an immediate means of safe water provision for vulnerable populations, efforts should be focused on this goal and not on commercialization. Money will have to be committed upfront, with no expectations for recouping costs or for the private sector to commit substantial resources in such an uncertain climate. Any higher expectations would be a fantasy.

4 Policy: National and International Policy Efforts to Support HWTS Scale-up

"By 2015, 30 countries have established policies on household water treatment and safe storage."[390]

4.1 Introduction

In the last chapter, we explored efforts to scale up HWTS in Ghana and the challenges that were encountered. Let us now consider the context in which these and other HWTS activities take place in Ghana and worldwide and how this context is changing. The "enabling environment" has become a concept commonly heard in discussions among WASH and HWTS sector stakeholders and in the scientific and grey literature.[391,392,393,394] As explained by Tilley et al. 2014, an enabling environment provides the framework and conditions necessary in a society to support the uptake and sustained use of technologies.[395] Specific to HWTS, Ojomo et al. 2015 explored enablers and barriers to effective HWTS implementation, grouping these factors into six domains: "user guidance on HWTS products; resource availability; standards, certification and regulations; integration and collaboration; user preferences; and market strategies."[396] Our exploration in the previous chapter of HWTS efforts in Ghana included attempts to employ the last of these domains - market strategies. We'll again focus on market strategies in this chapter but also bring in another of the six domains on which there's been increasing emphasis in the HWTS sector: standards, certification and regulations.

When considering how to foster an enabling environment for HWTS, there's significant potential for the government to contribute to public confidence in HWTS by taking on the role of ensuring the safety and performance of HWTS products through adoption of "internationally harmonized, evidence-based standards" and the application of "practical and affordable testing and certification procedures,"[397] whether the products are being implemented by NGOs or sold directly to consumers. In addition to the critical role of the government in creating an enabling environment, there is also an important role the WHO could play in developing these international standards. In the past, the WHO has played such a role in other sectors. For example, the organization developed standards for insecticide-treated bed nets, and the WHO's Pesticides Evaluation Scheme moved the sector toward standardized performance standards and testing procedures.[398] In fact, having identified the need for such standards and testing procedures for HWTS products, the WHO initiated the process of developing performance standard and testing guidelines in 2009.[399] We'll explore the resulting WHO International Scheme to Evaluate Household Water Treatment Technologies (the Scheme) in the latter half of this chapter.

Such standards and certification procedures require the support of regulation and enforcement, as well as a policy environment that approves of and legitimizes HWTS.[400] Recognizing this, the International Network to Promote Household Water Treatment and Safe Storage (the Network), co-hosted by the WHO and UNICEF, established in 2011 a policy-based target to facilitate HWTS scale-up and accelerate policy efforts: to have 30 countries with established policies on HWTS by 2015.[401] With this target in mind, the Network has since supported country governments to develop HWTS-specific strategies or incorporate HWTS into broader WASH policies. This support has taken a number of forms including providing consulting support on the writing and revision of policies and hosting "regional integration and policy strengthening workshops" to bring stakeholders[p] from different counties together to share challenges faced, lessons learned and progress made toward scaling up HWTS.[402]

Within this context, Ghana serves as a critical case. Specific to the Network's policy target, Ghana began developing a National Strategy for HWTS (the Strategy) in 2010 and finalized this strategy and its supporting documents in May 2014. The Network's 2012 global survey found that Ghana was one of five (out of 46 responding countries) with HWTS-specific targets and one of only two with national strategies for HWTS, as opposed to considering HWTS in national policy structures or not at all.[403] The global survey also looked at other elements important for achieving scale-up, and Ghana was one of three that had all five elements – national policy, HWTS target, coordinating structure, regulation and certification. The survey report set forth Ghana as "an example of a country… that is actively working at the national level to scale-up HWTS," citing the Strategy (although it wasn't finalized until 2014, as noted above) and the plans it laid out to:

- Create a product certification and labeling system;
- Evaluate HWTS options for emergency response; and
- Collaborate with other actors, such as NGOs and the private sector, to pilot new HWTS products.[404]

Further, Kweku Quansah, the HWTS lead for Ghana and its strategy development, has participated in and presented at many international HWTS events, including the Network's 2014 and 2015 Annual Meeting, which is hosted at the University of North Carolina's Water and Health Conference every year, and the WHO-hosted regional

[p] The WHO identifies these stakeholders as representative from the ministries of health and water in addition to HWTS researchers, manufacturers and implementers (WHO 2012).

workshops in Ghana in May 2013 and Ethiopia in May 2016. This exposure has allowed for external feedback from the HWTS sector and increased the sector's awareness of Ghana's efforts. With an established HWTS strategy and supporting documents, Ghana stands poised to take the next steps – rolling out the strategy and seeing if it is effective in supporting the scale up of HWTS in the country.

In this chapter, I will review and discuss the Network and the Ghanaian government's efforts to establish a HWTS-specific policy in Ghana and the Network's efforts to develop and apply international standards and certification for HWTS products. I'll also discuss how the result of these efforts - Ghana's National Strategy for HWTS and the WHO's International Scheme to Evaluate HWT Technologies - contribute to the enabling environment for HWTS in Ghana, specifically, the two domains of market strategies and standards, certification and regulations. This will involve drawing from the experiences presented in the last chapter as well as incorporating information obtained from other HWTS stakeholders who have been involved in the Strategy and the Scheme's development. I will argue that Ghana's Strategy and its supporting documents, while ambitious, do not effectively address the current challenges to scaling-up HWTS in Ghana and, similar to the findings in the last chapter, fall victim to an emphasis on commercialization that will not effectively reach the target vulnerable populations. Furthermore, the WHO's Scheme in its current form does not meet the needs of the Ghanaian government with respect to certification and regulation of HWTS products nor does it support country-level commercialization of HWTS.

4.2 Field Work

As with the previous chapter, this chapter is a compilation of what I've learned through interviews and observation, supported by a review of the literature that builds off of that performed for the first chapter, but with a greater emphasis on policy documents and relevant gray literature. From June 2011 to April 2015, I conducted 33 semi-structured interviews with 32 interviewees, in person or over Skype or telephone. A complete list of these interviews can be found in Appendix E. These interviews largely focused on the development of Ghana's National Strategy for HWTS but also included interviews on the WASH policy landscape in Ghana as well as WASH sector activities that were happening in parallel with HWTS-specific efforts. Interviews were recorded with the respondents' permission, according to the guidelines of the Johns Hopkins University Institutional review board. If the respondents did not want to be recorded, I took notes. I then transcribed the recorded interviews, and the transcriptions were made available to respondents for their review and comments.

The majority of in-person interviews and observations took place in Ghana. I began my exploration of the broader WASH policy landscape at the end of my May-June 2011 trip, but the bulk of my fieldwork on Ghana's Strategy took place from September to December 2012. During this time period, in addition to interviews, I observed a meeting of Ghana's HWTS Technical Working Group as well as two meetings of the National Level Learning Alliance Platform, which is "a WASH sector multi stakeholder platform with the overall goal of improving sector learning and dialogue… hosted by the Ghana WASH Resource Centre Network."[405] In May 2013, I returned to Ghana for the West Africa Regional HWTS Workshop, organized by the MLGRD in collaboration with the MWRWH as well as the Government of Ghana, UNICEF, and the WHO. The stated goal of the workshop was: "To support participating countries to identify existing policies and develop/strengthen, strategies and regulation of HWTS to support effective implementation and integration with other household environmental health interventions." During this workshop, I attended presentations by and observed and participated in discussions among attendees, who represented a wide range of governmental, non-governmental, and for-profit WASH stakeholders in Ghana, the Gambia, Liberia, Sierra Leone, and Nigeria.

With regards to fieldwork focused on the Network's Scheme, I attended the 2013, 2014 and 2015 Annual Meeting of the Network at the UNC Water and Health Conference. At the 2014 conference, the WHO, UNICEF and the Water Institute at UNC convened a side event on the Scheme, which I attended. I also participated in two other side events in which the Scheme was a central topic of discussion: "Biosand Filters: Defining Future Research Directions for Greater Impact" and "Ceramic Pot Filters: Current Research, Future Directions and Defining Next Steps." In 2015, in addition to the Annual Meeting, I attended the WHO's side event "Beyond Testing: Capacity Building Under the WHO International Scheme to Evaluation Household Water Treatment Technologies."

Although my fieldwork in Ghana ended in 2013 and the last interview I conducted for this chapter was in April 2015, I have continued correspondence with a number of my respondents over the past year and a half. Furthermore, I have remained actively engaged in the global HWTS sector as well as the Ghanaian HWTS sector not only through attending the UNC Conference and the 2015 Annual Network Meeting but also through continued review of the literature and, more importantly, interaction, communication and collaboration with sector stakeholders. This continued engagement has been facilitated by my role as Knowledge and Research Coordinator for the Centre for Affordable Water and Sanitation Technology (CAWST),[q] which I began in August 2015. In this role, I specialize in knowledge management around HWTS products and policy. Toward this end, I serve as the communications point person for the WHO with respect to the Scheme and other Network activities as well as activities specific to Ghana's Strategy.

4.3 HWTS Regulation and Policy in Ghana

4.3.1 Regulation

Before we explore the development and content of Ghana's National Strategy for HWTS, I'd like to first consider the regulatory environment in which HWTS implementations had been taking place in Ghana before the strategy was established. In addition to a policy environment that supports HWTS, there must also be a regulatory environment that enforces standards and guidelines. Before the strategy's development, no policy or government guidelines on HWTS products had been established.[406] There were, however, two government agencies that could conceivably play a role in regulating HWTS activities: the Food and Drug Association (FDA) and the Ghana Standards Authority (GSA). The FDA was established by the Food and Drugs Act of 1992 and focuses on public health.[407] According to the Food and Drugs Act, it is a punishable offense to sell food intended but unfit for human consumption, with water being included in the official definition of food.[408] Considering the different types of HWTS products, it

[q] CAWST is a non-profit consultancy that provides capacity development services to organizations implementing WASH programs, including: training workshops, consulting support and education resources.

seems likely that consumable (as opposed to durable) HWTS products such as liquid chlorine and chlorine tablets, which are added to water for disinfection, would fall under the FDA's regulatory authority.

The GSA, established by the Standards Authority Act of 1967, focuses on developing standards for the regulation of trade.[409] These standards are intended to ensure the quality of goods produced in Ghana and to help promote efficiency and development in industry.[410] The water quality requirements for drinking water established by the GSA set the guideline for E. coli at non-detect for any 100mL sample, which matches the standard set in the WHO's Guidelines for Drinking Water Quality. And Ghana is not unique in following the WHO's guidelines. A 2013 WHO regulatory scan of 100 countries' water safety regulations and standards found that Ghana was one of 99 countries whose E. coli standard matched that of the WHO's Guidelines for Drinking Water Quality.[411] Beyond the development of standards, the GSA also tests, inspects and certifies commercial activities. In some instances, such certification is voluntary, with the motivation being that producers can use the GSA certification seal on packaging after being certified. In others, certification is mandatory, as in the case the FDA requiring GSA certification of a product that has health and safety implications. Based on this case, one can imagine GSB certification being required of HWTS products manufactured in Ghana and specifically durable products such as filters.[412]

And in fact, Vestergaard submitted the LifeStraw Family 1.0 filter to the GSA for certification right after launching their office in Ghana. In addition to the filter itself, they submitted a protocol for testing the filter. The Water Research Institute, within the Council for Scientific and Industrial Research, then tested the filter and provided

Vestergaard with documentation that the filter met the WHO standard and Ghana's standards. Ms. Anaan of Vestergaard told me that this certification did not require renewal, unlike certification through the FDA, which only lasts for a period of four years and is then subject to renewal.[413] Although the decision by Vestergaard to seek certification of the LifeStraw Family 1.0 through the GSB seems to have been a straightforward one, the existence of two government authorities, the potential overlap between their regulatory responsibilities with respect to water, and the lack of HWTS-specific guidelines created an environment of uncertainty. This uncertainty emerged with particular clarity during my field work and is well-exemplified by two particular instances.

The first instance involved Beth Devroy of Ghanapreneurs and her decision making process with respect to certification of the Hydraid biosand filter in Ghana. In the fall of 2012, Ms. Devroy reflected on what was learned during the marketing exercise performed in the Ministries area of Accra, which targeted an educated, civil servant population. She considered the implications this experience would have for how she would pursue certification of the filters in a way that would be recognized by consumers. In contemplating her options, she spoke of needing a certification of water quality that Ghanaians would trust. Although she had testing results from the manufacturer Triple Quest, she did not think that this information would resonate with potential customers. Feedback from participants in the market storm had led her to conclude that people most respected the testing and certification by the GSA. From there, she moved on to consider which entity within Ghana would be best for testing: a research lab at the Kwame Nkrumah University of Science and Technology (KNUST), a testing lab at the Water

Resources Institute (WRI), or the GSA itself. She concluded that they should have the filter tested by KNUST and WRI and bring the results to the GSA for approval. Her rationale for this was that the GSA would send out the unit for testing, so she would prefer to have control over the testing.[414]

This instance serves as an example of the potential waste of time, energy and resources in performing unnecessary testing if the actual requirements are not made clear and easily accessible. Furthermore, Ms. Devroy's interest in pursuing certification was not legally motivated but rather financially motivated, as the certification was not to ensure compliance with a set of guidelines but rather to instill in consumers a sense of trust when considering Hydraid for treating water in their homes. This instance makes it clear that, at least for Ms. Devroy, there was not any sense of obligation or requirement to certify Hydraid before selling, distributing and implementing the product in Ghana (although she had obtained GSA approval of the filters when they were in port).[415]

The second instance occurred at the West Africa Regional HWTS Workshop held in Accra in May 2013. Here, there was a lot of confusion amongst Ghanaian participants over which entity was in charge of HWTS regulation and certification. All were in agreement that the FDA regulates consumable products and that certification is required for the importation and sales of chemical HWTS products like chlorine. For example, one participant explained to me that Procter & Gamble's Purifier of Water was not available in Ghana because the company had not gone through the required testing and certification process. As for filters, the general consensus was that such products would fall under the GSA's authority, but that submission for testing was voluntary, not required. Participants expressed concern over this disparity between requirements for chemical products and mechanical products (filters). Ghana is not alone, however, in having different standards and testing for chemical and mechanical products. For example, in Ethiopia, chemical HWTS products are regulated as a pharmaceutical product and must undergo a very stringent evaluation that can take years.[416]

In addition to the difference in standards and testing between these two types of products, participants were unsure as to whether or not there would be differences between those for locally-made mechanical products (e.g. PHW's ceramic pot filter) and those for imported products (e.g. LifeStraw Family). The discussion also brought in another potential actor to add to the confusion: the Environmental Health and Sanitation Directorate, which is responsible for water quality testing during premises inspection. What caused the greatest concern, however, was the mention of a legislative instrument being considered that would require that HWTS products meet the WHO guidelines for water quality, with potential legal ramifications if a product did not meet these guidelines and a consumer then argued that he or she was made sick as a result. As such, this session within the workshop, in spite of involving many stakeholders with a breadth and depth of experience, generated more questions than answers around HWTS regulation and certification in Ghana.

4.3.2 The Strategy and Its Supporting Documents

Development

The development of Ghana's National Strategy for HWTS began in 2010, with funding and support from UNICEF.[417] To initiate the process, a HWTS Technical Working Group was created. The Technical Working Group consisted of relevant stakeholders from government ministries, the private sector and NGOs. Among these stakeholders were Kweku Quansah of the Environmental Health and Sanitation Directorate (EHSD) within the Ministry of Local Government and Rural Development (MLGRD) and Patricia Buah of the Water Directorate within the Ministry of Water Resources, Works and Housing (MWRWH). Mr. Quansah and Ms. Buah were the heads of the Technical Working Group.[418] EHSD was to be the lead for the Strategy's development within the government's ministries. The decision to house HWTS in EHSD took significant time and was viewed as a critical step in the strategy development process. Although issues around water generally fall to the Water Directorate, stakeholders decided that the key focus of the HWTS strategy would be behavior change, and EHSD is seen as having particular strength with respect to behavior change, given its lead role in the Community Led Total Sanitation (CLTS) program.[419,420] The reasoning behind this decision will be discussed later.

The documentation process began when the WHO and UNICEF put out a call for a consultant to perform an assessment of HWTS in Ghana. Marion Kyomuhendo, a consultant from Uganda with behavior change communication expertise but without prior HWTS experience applied and was hired. Her assignment was to perform case studies on specific HWTS products as well as an assessment of the status of HWTS in Ghana.[421] This assessment focused on what technologies were currently being used and what practices around household water were most common. Furthermore, it explored to what extent the public was aware of the health risks of consuming unsafe water and of HWTS as an option to minimize these risks.[422]

Based on the findings of the case studies and the landscape assessment as well as input from the members of the Technical Working Group, Ms. Kyomuhendo wrote an initial draft of the National Strategy and handed it over to the technical working group in February 2011.[423] Over the next two years, the Technical Working Group revised the strategy significantly, with input from others, including Michael Forson, then a WASH Specialist for UNICEF based at the headquarters in NYC, and Steven Ntow, a WASH consultant and the founder of WASHealth Solutions in Ghana. Outside of input from the Technical Working Group and consultants, a validation workshop was held in May of 2012 to obtain feedback from the broader WASH community in Ghana.[424,425]

In the Fall of 2012, I had the opportunity to check in with Ms. Anaan of Vestergaard, Ms. Jackson of PHW, and Ms. Devroy of Ghanapreneurs to hear their thoughts on the strategy and its implications for their work and for making progress toward scale up of HWTS in Ghana. Ms. Anaan and Ms. Jackson had both participated in the strategy development process as members of the HWTS Technical Working Group. When asked what the biggest challenge would be in rolling out the strategy, Ms. Anaan responded quickly and clearly: funding. UNICEF would provide seed money to start the process, but beyond that, funding was unclear, although the conversation repeatedly returned to public private partnerships. Ms. Anaan wondered aloud if the government expected the private sector to come in and offer their products for free. She expressed a desire to first "spell out" the details of the public private partnership and a reluctance to commit to any contributions before this was done.[426]

For Ms. Jackson, the development of the strategy signaled an increased awareness within the government of HWTS and its potential contributions to improved health. She credited this increased awareness in large part to the flood relief efforts and the Guinea worm eradication campaign. When asked how she thought the policy would affect PHW's activities, she responded frankly: "In the end, very little because we're going to keep doing what we're doing, and the policy is not coming with any money or support, financial support for it, so I don't think that it's going to make a big difference in the end."[427] Similarly, Ms. Devroy did not anticipate the strategy would have an impact. Her opinion was: if the government can't manage regulation and policy enforcement at the community level, how are they going to do so at the household level?

In May 2013, the Ghanaian Government, with support from the WHO, UNICEF and the Network, hosted the West Africa Regional HWTS Workshop. The intent of this workshop was to bring together Anglophone West African countries to share lessons learned and to help them move toward HWTS policies of their own. Other such workshops were also held for East Africa and Southern Africa in 2011 and 2012, respectively.[428] At the West African Workshop, there were many stakeholders from the Ghana HWTS sector in attendance, including Mr. Quansah, Ms. Buah, and others from government ministries. Ms. Anaan, Ms. Jackson and Ms. Devroy were also in attendance. Some of the key discussion points from this workshop will be addressed in the next section.

Following the workshop, a consulting company, Rapha Consult, was brought on to incorporate the internal and external feedback and finalize the strategy and its supporting documents.[429] In May 2014, all three documents were finalized and ready for circulation. In establishing a National Strategy for HWTS, Ghana became one of the first countries to achieve the Network's goal with respect to establishing a policy that specifically addressed HWTS. [430]

The Basics

In the previous chapter, we explored the cases of LifeStraw Family 1.0, Hydraid and ceramic pot filters and the challenges that Vestergaard, Ghanapreneurs and PHW, respectively, encountered when trying to scale up their activities through direct sales and other strategies. We've also identified uncertainty generally around the impact of the strategy on current HWTS implementation activities and more specifically around the roles and responsibilities of different government authorities in regulation and certification. Let us turn now to the content of the strategy and its supporting documents, starting with an overview and then exploring how they address – or fail to address – the previously identified challenges to and uncertainties around scaling up HWTS in Ghana.

The National Strategy for Household Water Treatment and Safe Storage in Ghana (the Strategy), published in May 2014, has two supporting documents, which were published at the same time: (1) the Scale-up Model; and (2) the Private Sector Participation Framework. These documents, which are 17 pages, 16 pages and 19 pages, respectively, are written concisely and clearly, using terms that are well known within the WASH and HWTS sectors, including: enabling environment, vulnerable populations, integrated approach and behavior change communication. The goal of the Strategy and its supporting documents is: "to contribute to achieving improved health for all by 2025… by pursuing sustainable and effective promotion and adoption of HWTS as a behavior through the use of appropriate technologies that make drinking water safe at the point of use."[431] These documents are governed by guiding principles that are also found in relevant policy documents such as the Environmental Sanitation Policy, the National Water Policy and the National Health Policy. The principles are: partnerships, integrated approach, fundamental rights of all people, equity and gender sensitivity, subsidiarity and the greatest common good to society. With the established goal and guiding principles, the documents establish a high set of expectations.

The Strategy

Specific to the Strategy is an extensive list of strategic actions that fall under seven thematic areas: (1) policy and institutional development; (2) technology; (3) consumer engagement; (4) emergency response; (5) research and knowledge management; (6) financing and partnerships; and (7) monitoring and evaluation. Within each thematic area, there are anywhere from two to eleven strategic actions. Each strategic action in itself will require a significant amount of time, effort and resources from a range of stakeholders. For example, under Technology, one strategic action is: "Catalyze creative supply channels and distribution systems to ensure that effective HWTS reach the most vulnerable (and often remote) populations, including pregnant women, aged, physically challenged and persons living with HIV and AIDS."[432] As seen in the specific cases for LifeStraw Family 1.0, Hydraid and ceramic pot filters, achieving this has proven elusive for stakeholders in Ghana, and it is also a persistent challenge worldwide. Considering this one, sweeping strategic action in combination with the other 34 actions, one can imagine just how much is proposed in the strategy.

And who will achieve that which is proposed in the Strategy? Following the strategic actions, the Strategy sets forth the Roles and Responsibilities, with the Ministry of Local Government and Rural Development (MLGRD) as the lead ministry for coordinating strategy implementation. Within MLGRD is the Environmental Health and Sanitation Directorate (EHSD), and within EHSD is Mr. Kweku Quansah, who leads and coordinates all of the HWTS program activities (we will return later to the decision to house HWTS in EHSD).

In addition to the role and responsibilities of MLGRD, the Strategy also establishes the roles and responsibilities of: Ministry of Water Resources, Works and Housing; Ministry of Health and Ghana Health Services; Ministry of Education and Ghana Education Service; Ministry of Finance; Ministry of Energy; Community Water and Sanitation Agency; Ghana Water Company Limited; Ghana Standards Authority; National Disaster Management Organization; and Metropolitan, Municipal and District Assemblies.[433] Having set forth so much in such a relatively short document, the utility of the two supporting documents becomes clear. Let us turn, then to the first of these two documents - the Scale-up Model.

The Scale-up Model

The purpose of the Scale-up model is to detail the three-pronged implementation approach for HWTS scale-up across Ghana while at the same time addressing the Strategy's strategic actions. The three-pronged approach, which is first introduced in the executive summary, consists of: (1) behavior-first approach; (2) public private partnership approach; and (3) commercial/business approach. Before providing further information on these three approaches, the Scale-up Model first breaks down the overall goal of improved health for all by 2025 into three sets of HWTS-specific objectives by year: 2015, 2020 and 2025, with three objectives under each target year. The three objectives for a given target year set goals for the percentage of the population who: are aware of HWTS; have "adequate knowledge" on the use of HWTS and its health-related benefits; and are practicing safe, context-appropriate HWTS methods. For example, the objectives for 2025 are as follows:

- 100% of the entire population is aware of HWTS;
- 90% of the entire population has adequate knowledge on HWTS use and its health benefits; and
- 75% of the entire population consistently practices safe, context-appropriate HWTS methods.

While the objectives for 2025 are a percentage of the country's entire population, the objectives for 2015 and 2020 make use of the country's regions. The initial focus for 2015 is on the five most vulnerable regions - Central, Volta, Northern, Upper East and Upper West. This phase is followed by an expansion to include the two most populous regions - Greater Accra and Ashanti - in 2020, and then finally an inclusion of all regions for 2025. To achieve these objectives, the scale-up model is to rely on the three interdependent approaches listed above, which the reader learns are currently in use for the ongoing Safe Excreta Disposal and Hand-washing with Soap initiatives. The HWTS initiative will not only make use of the same approaches but also be integrated into these ongoing initiatives as opposed to being implemented separately.[434]

Now, what are these approaches to consist of? The Strategy has defined HWTS as a behavior, and the behavior-first approach focuses on this. The aim of this approach is to increase awareness of and knowledge on HWTS through 5 behavior change activities. The first activity within the approach is to determine the baseline level of behavior and practice; the next activity focuses on building the knowledge of households and communities on water quality, waterborne diseases, and HWTS. The approach is also to include promotion of HWTS at the community level through "Behavior Change Communication techniques and campaigns to create demand for technologies." A subsequent activity that will aid in continued HWTS promotion is identifying community-level champions to continue promotion and reinforce behavior change. And in parallel to these four behavior change activities is an assessment of the feasibility of existing HWTS technologies.[435] Although feasibility is not defined, one may infer that it involves ease of use, robustness and appropriateness, as these play into sustained behavior change.

The public private partnership approach, as its name implies, is intended to optimize private sector potential by partnering with public sector institutions. Through this partnership, the goal is to develop and implement "innovative programs" that will improve the uptake of HWTS in Ghana. Included in this section are two proposed activities: 1) engaging with the private sector to provide appropriate, sustainable products that support behavior change in households and communities; and 2) employing financing mechanisms such as micro-credit and flexible repayment terms.

The commercial/business approach also engages the private sector. It focuses on creating an enabling environment for private sector participation in HWTS activities through business initiatives, with the motivation for this participation being the opportunity for full cost recovery and even potential profitability. The central activity in this approach is set forth as follows: “Encouraging the private sector to develop and market HWTS products through advertisement and interactive sessions with communities and households to demonstrate the efficacy of their products, basic operation and maintenance, and after-sales services and support.”[436] The expectation upon which this approach is built is that the potential profitability will encourage market entry, which in turn will lead to competition that encourages companies to reduce prices, improve product quality, innovate, and market their products in order to increase their market share. With more companies making HWTS products, availability and accessibility to these products will ideally improve through increased production and an extension of distribution and supply chains. Increased private sector activity is also expected to create and increase the public’s interest in HWTS products.[437] Given that both the public private partnership approach and the commercial/business approach rely heavily on private sector participation, the need for a PSP Framework to provide further detail is clear.

In addition to introducing the three approaches, the overview of the scale-up model in this document includes a three phase geographical focus, which ties into the 2015, 2020 and 2025 objectives, and identifies the priority communities: those which are open defecation free; those with greater than 50% latrine coverage; and those in need of emergency response, whether due to high endemic disease levels or an epidemic. It also includes an introduction to implementation arrangements. These arrangements will take place within the context of the National Water Policy and Environmental Policy, which rely on decentralization and are implemented at the national, regional and district levels.

Building off of the decentralization program, this section puts great emphasis on the role of District Assemblies with respect to implementing Government policies and programs. It is expected, therefore, that District Assemblies will lead the implementation of the HWTS program. This leadership role will involve: integrating the Strategy into existing district-level plans; working with EHSD-MLGRD to train relevant district level staff on the Strategy; providing the necessary resources to district- and area council-level teams for HWTS promotion; ensuring that these teams provide HWTS training to existing community-level structures; and managing HWTS promotion contracts with NGOs and the private sector.

Based on how these responsibilities are laid out for the District Assemblies, one may infer that it is expected that current district- and area council-level staff (e.g. Environment Health Officers, Community Development Officers and extension staff) will add these responsibilities to their existing responsibilities, hence the integration of the HWTS program into ongoing initiatives as opposed to being a stand-alone program with designated staff. Further detail is provided in a one-page table at the end of the document, which constitutes the implementation arrangements, work plan and institutional arrangements. This work plan can be seen in Appendix F, presented as it is in the Scale-up Model document.

The final section of the Scale-up Model is on the Monitoring and Evaluation Framework. This framework is intended to facilitate measuring the progress made toward the objectives set out at the beginning of the document. This progress will be measured at the national, regional and district levels based on indicators that parallel the objectives: awareness, knowledge and practice of HWTS. The knowledge and awareness indicators are combined into a set of four, and households qualify as "aware" if they meet three of the four indicators:

- Think their neighbors and others in the community practice HWTS
- Report receiving HWTS promotion and training
- Are able to link HWTS to diarrheal disease reduction
- Are able to name at least one effective HWTS technology

The practice indicators focus on treatment and safe storage, and household qualify as "practicing" if the meet one of the 2 criteria:

- Report treating their water (confirmed through observation or demonstration of treatment method)
- Store their water safely in a designated, securely covered vessel that is out of reach of infants and animals

These indicators are to be incorporated into existing periodic surveys such as the Multiple Indicator Cluster Survey and the Ghana Demographic and Health Survey, which are performed by the Ghana Statistical Service. Additionally, EHSD-MLGRD is to commission additional surveys when necessary to measure the Strategy's impact. Although the Monitoring and Evaluation Framework emphasizes measuring progress around behavior change, two of the three approaches in the Scale-up Model rely heavily upon private sector participation.[438] And so, we turn now to the PSP Framework to learn more about how the private sector is to be involved in the Strategy and HWTS implementation in Ghana.

The Private Sector Participation Framework

The PSP Framework is geared toward effectively engaging the appropriate private sector actors for formal involvement in HWTS scale-up efforts. In the section that provides an overview of the Strategy's goal and specific objectives, the PSP Framework adds an emphasis on the key role to be played by the private sector in implementing the strategy, saying: "government recognizes the important role of the private sector and seeks to create an enabling environment that ensures that the private sector is incentivized to support the citizenry with affordable and effective HWTS technologies, products, services and options."[439] After the introduction and overview, the remainder of the document is dedicated to implementation arrangements, roles and responsibilities of the public and private sectors, and types of HWTS arrangements.

Under Implementation Arrangements, the Government first sets forth pre-conditions for private sector participation, namely that a private sector entity interested in participating must be legally registered and possess the permits and approvals required for operating a business in Ghana. Having met the pre-conditions, the private sector entity is then advised to formalize its participation by creating and signing a Memorandum of Understanding (MoU) with the relevant Metropolitan, Municipal and District Assemblies (MMDAs), determined by where it plans to operate. It is then the role of EHSD-MLGRD to evaluate the the product/service provided by the private sector entity before endorsing the MoU. Although EHSD-MLGRD assesses the product/service before endorsing an MOU, all products and services are also required to go through formal registration and certification. This registration and certification process requires certification according to International Organization for Standardization (ISO) standards and endorsement from both the GSA and FDA. And finally, a monitoring and evaluation plan will be built into existing platforms to measure development, delivery and uptake of private sector HWTS products and services. These implementation arrangements require both the public and the private sector. The roles of each are set out in the following two sections of the PSP Framework.

Within the PSP Framework, the roles and responsibilities of the public sector are: developing and reviewing policy; setting standards and guidelines; providing technical assistance for technology selection; performing monitoring and evaluation; approving public-private partnership (PPP) projects and contracts; providing knowledge management services; and implementing behavior change communication. For any PPP project, the National PPP policy is to be used to define the roles and responsibilities.

As for the private sector, the key roles and responsibilities are: obtaining legal registration to operate in Ghana and fulfilling the required tax obligations; developing effective and appropriate HWTS products and services; marketing HWTS products and services; transferring HWTS knowledge and skills to the Ghanaian workforce; providing after-sales support for HWTS products and services; undertaking research and development to reduce costs and ensure sustainability of HWTS products and services; developing and maintaining supply chains; and developing and implementing financing mechanisms that avoid direct subsidization of HWTS products and services. In short, the responsibility of a private sector entity is to be a successful business.

Finally, the section on HWTS arrangements presents six potential arrangements that the private sector could enter into with MMDAs. These possible arrangements are intended to provide examples of different levels of involvement by the private sector and

MMDAs. A specific arrangement is to be developed depending on the needs of a given location (e.g. district, community) and the private sector entity's capacity and resources. The list of arrangements is not intended to be exhaustive but rather to imagine possible arrangements that may arise within Ghana, and there appears to be significant overlap between some of the arrangements as they are presented. The PSP Framework ends with these potential arrangements, which are summarized here:

- Private sector production and delivery of HWTS product or service with regulation by MMDA;
- Participation by MMDA in HWTS product development followed by a service contract between MMDA and private sector entity for supply and distribution;
- Private sector development of specific HWTS product or service under a commercial contract with the public sector;
- Government engagement with a private sector entity through a franchise agreement in which the private sector delivers a specific HWTS service for a designated period of time;
- Private sector partnership with MMDA in a joint venture to deliver HWTS products and services to individual households and institutions, with private sector entity providing the technical product or service, MMDA undertaking behavior change activities and both parties sharing responsibilities and risks; and
- Private sector partnership with public sector organization to deliver HWTS products and services, with none of the assets belonging to the Government.

The purpose of this content overview was to provide a brief look at the key sections of each document and their emphases and themes, the type of activities that are planned in each, and the expectations that are established through the roles and responsibilities. We'll now focus in on the elements of the Strategy and its supporting documents that are most relevant to the challenges and issues identified.

4.3.3 Discussion

HWTS as a Behavior

The overarching goal of the Strategy, as presented in the previous section is: "to contribute to achieving improved health for all by 2024… by pursuing sustainable and effective promotion and adoption of HWTS as a behavior through the use of appropriate technologies that make drinking water safe at the point of use."[440] In this section, we'll focus on the definition of HWTS as a behavior, namely its importance and its implications. So first, what is the significance behind defining HWTS as a behavior? Why does achieving behavior change matter?

As discussed in the previous chapter, achieving scale-up of HWTS requires not only coverage but also uptake; that is, HWTS products must not only be made available and accessible to the target population but also be used correctly, consistently and continuously by this population.[441] Simply put, distribution and implementation of an HWTS product will not achieve the desired impact if the intended end users to do not actually use the product.

Not surprisingly, studies have confirmed the importance of uptake to not only microbiological effectiveness but also public health impact. Luoto et al. 2011 found that households self-reporting use of any of four HWTS products had significantly larger reductions in E. coli than control households.[442] The 2015 Cochrane Review by Clasen et al. found that larger reductions in diarrhea were achieved in trials reporting higher compliance.[443] Conversely, a decline in compliance from 100% to 90% was found to reduce the anticipated health improvements resulting from household water treatment by as much as 96%, nearly eliminating the benefits of treatment.[444] Sustained uptake matters.

Achieving coverage alone often proves challenging, as we saw in the particular case of Ceramica Tamakloe in the last chapter. Achieving uptake is no less challenging. Although in the last chapter I presented relatively high rates of compliance (uptake), the majority of these findings were based on self-reported use as opposed to measured use. The former is prone to bias,[445] the latter is difficult to do effectively. In cases of treatment using chlorine, chlorine residual in treated water can be measured, and in other interventions, improvement in quality of stored water can also be measured to evaluate compliance. Such measurements, however, do not fully capture all aspects of correct, consistent and continuous use, for example, treatment year-round as opposed to seasonally and exclusive consumption of treated water by all family members.[446,447] Furthermore, maintaining uptake has been found to be an additional challenge, as studies have found that usage rates drop significantly after an intervention ends.[448,449] Achieving and maintaining meaningful uptake of HWTS will require achieving and maintaining behavior change to ensure correct, consistent and continuous use. Behavior change matters. And defining HWTS as a behavior implies a recognition of the importance of behavior change in scaling-up HWTS.

The choice to define HWTS as a behavior has another important implication, as well. When discussing where to house HWTS, the conversation began at the obvious place - the Water Directorate in the Ministry of Water Resources, Works and Housing - but the majority of the budget is dedicated to maintenance and incoming funding from donors was dedicated to infrastructure development.[450] With respect to water treatment and supply, the Community Water and Sanitation Agency and the Ghana Water Company focus on centralized treatment solutions - albeit on different scales - in rural and urban areas, respectively. Next was the Ministry of Health, given the health implications of HWTS; however, the Environmental Health and Sanitation Directorate (EHSD), formerly within the Ministry of Health, had been shifted over to the Ministry of Local Government and Rural Development in the early 2000s. The EHSD was determined to be the best home for HWTS because, according to Mr. Quansah, "The bottom line is we are seeing this as a behavior, not as an infrastructure."[451] Since 2007, EHSD had taken on the behavior change efforts around safe excreta disposal and hand-washing with soap. Having recognized that household water treatment and safe storage was lagging behind these two initiatives, EHSD saw an opportunity to piggy back HWTS onto its existing behavior change initiatives.[452]

In this way, by defining HWTS as a behavior, EHSD was made the appropriate home of HWTS efforts in Ghana, making it possible to integrate these efforts into existing behavior change initiatives as opposed to creating a standalone HWTS initiative, which theoretically would require more money and additional staff. When asked about focusing on HWTS as a behavior, Harold Essuku, the consultant hired to finalize the Strategy and its supporting documents, explained: "Again, if we wanted to create a HWTS task force, funding would be a problem. And the best place to situate it was with the Environmental Health and Sanitation Directorate, where they have staff who already are supposed to go out and ensure that you have good quality water in place, in addition to keeping the environment clean and all of that. And it is actually part of their mandate."[453]

Housing HWTS in EHSD meant that at the local level, the task of providing HWTS messaging and support would fall on the 3,000 existing staff within the 216 Metropolitan, Municipal and District Authorities.[454] Theoretically, the responsibilities of these staff members - environmental health inspection, law enforcement and education - could be adapted to include HWTS indicators for inspection, laws and regulations for enforcement, and behavior change messaging for education. According to Mr. Esseku of Rapha Consult, who was also involved in the dissemination of the finalized Strategy and supporting documents, once the a manual was developed on HWTS and given to these staff, they were to take the key messages and incorporate them into what they were doing for the existing sanitation and hygiene campaigns. To my knowledge, such a manual is not yet available.

Mr. Esseku's involvement in the dissemination of the strategy consisted of hosting workshops in January and February 2015 for MMDA staff and staff of the Community Water and Sanitation Agency to provide an overview of the Strategy and its supporting documents. Mr. Esseku prepared presentation materials for use in all of the workshops. He undertook the first two dissemination workshops: one in the Central Region and one in the Volta Region. From what he knew, another two workshops were held during this period. In instances when Mr. Esseku was not available, the host would use his PowerPoint presentation.[455] In the two dissemination workshops he led, he had found that participants were generally receptive once they learned of the plans to integrate HWTS into existing responsibilities and initiatives:

> "There was a general fear that this was going to be a new burden that was going to be added to their schedule. But once they found out that this is an integral part of what we have been doing every time, lots of them shared their experiences. All the workshops, it was the same kind of feedback I had: We have been doing similar thing before, and we are happy this is coming to complement what we do. And we are happy there's not a totally new thing which is going to take all our time."[456]

If the staff didn't anticipate the Strategy bringing about change in their daily responsibilities, and no additional funding or new staff was dedicated to implementing the strategy at the MMDA level, it seemed to me that little change could be expected to come from this means of Strategy dissemination.

With respect to behavior change, the Strategy includes the following strategic action: "Use BCC [behavior change communication] strategies to create awareness and demand for effective HWTS."[457] The sub-actions focus almost entirely on the development and dissemination of information, education and communication (IEC) materials. Although no details are provided on the type of IEC materials to be generated and used, examples of different types of IEC materials include posters, puzzles and card games such as the cholera prevention poster from Haiti and images from a three pile sorting activity shown in Figure 13 below. Once created, these materials are to be integrated and coordinated with the IEC materials for other efforts around sanitation and health. [458] Based on this content and what I learned regarding dissemination of the Strategy and how local staff were to incorporate the Strategy into their daily responsibilities, I infer that the behavior change activities for HWTS would largely consist of traditional behavior change education and social marketing messages through local staff, with the support of the aforementioned IEC materials. These activities are standard in the WASH sector and in HWTS interventions, specifically, and often focus on the risks of untreated water or the benefits of HWTS and preventing waterborne disease.[459,460,461]

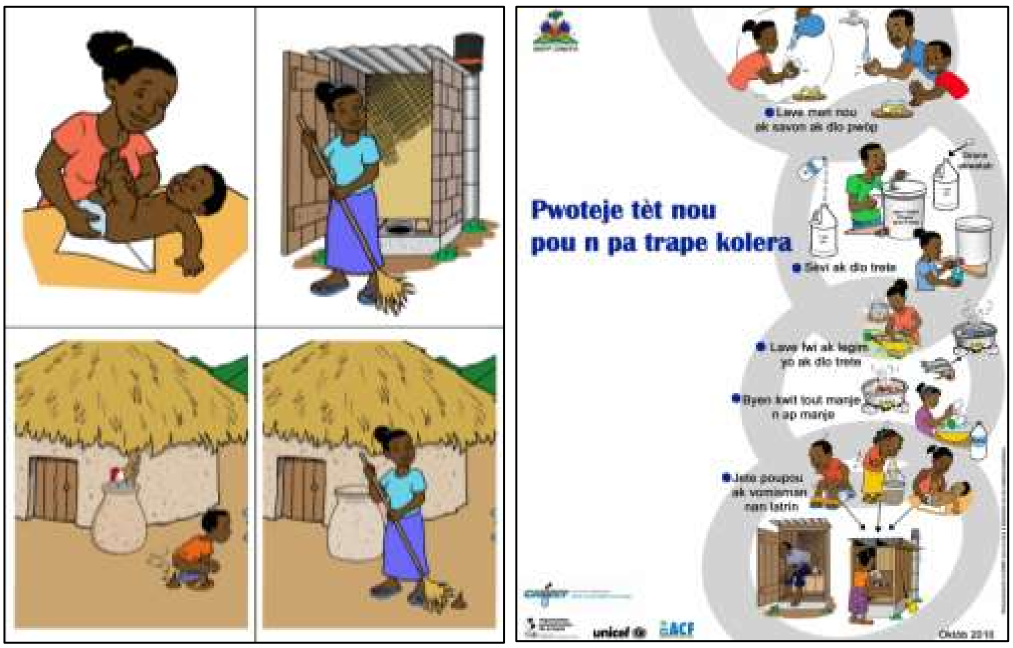


Figure 13. Example IEC materials[462]

Although such activities are standard practice in the sector, a recent review of literature on behavior change interventions for HWTS in low- and medium-development countries found limited available peer-reviewed behavioral research. Furthermore, in the literature that did exist, documentation of the theories behind interventions, the details of the interventions, and the evaluation of the interventions was lacking. The authors set out three possible explanations of how the limitations in behavior change research for HWTS could have contributed to the thus-far underwhelming uptake of HWTS interventions in low- and medium-development countries:

- Limited availability of published behavioral research specific to HWTS that could be used to support those implementing such interventions;
- Lack of enough detail in the available literature for implementers to be able to replicate the behavioral interventions or interpret evaluation results; and
- Research design that did not allow for evaluating the impact of behavior change interventions on uptake of HWTS technologies or assessing factors that motivated or inhibited behavior change.

Based on these findings, the authors concluded that the field of behavior change for HWTS is underdeveloped and that low uptake of HWTS could be attributed in part to a weak understanding of the determinants of HWTS-related behavior change.

Similar to what this literature review found, the Strategy lacks detail on the behavior change activities to be carried out as well as the theoretical backing behind the chosen activities. It is clear that greater thought and effort will be required to achieve HWTS uptake than tagging on a few additional tasks to the responsibilities of existing staff. Not only will it be necessary to plan behavior change activities beyond the development of IEC materials, but it will also be necessary to build the knowledge and skills of local staff around HWTS, behavior change communication, and effective integration of these activities into their existing responsibilities. In the WASH sector in general, lack of local capacity has been identified as a challenge to achieving the Sustainable Development Goals, and there are calls for investment in capacity building to address this need.[463,464] The capacity building needs around HWTS in Ghana are a specific example of this broader issue.

Integration of HWTS behavior change into other sanitation and health activities also comes into play with regards to where HWTS efforts will be focused. According to the Scale-up Model, the following communities will be prioritized for implementation: those that have achieved open defecation free status; those with over 50% latrine coverage; and those in need of emergency intervention. The first two criteria tie directly into EHSD's efforts around Community Led Total Sanitation (CLTS) and safe excreta disposal, which focus on ending the practice of open defecation and encouraging construction of latrines. Although I am not privy to the thought process behind selecting these criteria, I would imagine that the intent is to build off of the momentum of CLTS, the behavior change achieved around sanitation, and the activities undertaken to support this behavior change, such as the construction of latrines. Furthermore, achieving both improved sanitation and HWTS would more holistically address diarrheal disease by blocking multiple pathways of transmission.

In this way, these two criteria make sense, but prioritizing such communities makes it likely that those reached first will be the low-hanging fruit, the communities that are easiest to reach, instead of the most vulnerable populations. As a result, success may come quickly and easily early on but then be more difficult to achieve as the priority communities are checked off the list. The final criterion - communities in need of emergency intervention - cannot be argued against. Interestingly, the Scale-up Model identifies such communities as not only those suffering from epidemics but also those at risk of endemic disease. I would need to know more on how the latter is evaluated, but perhaps this would provide the opportunity to prioritize vulnerable populations. Generally, though, I would assume the third criterion would be applied in cases such as the floods that led to the mass distribution of ceramic pot filters as discussed in the previous chapter.

Overall, defining HWTS as a behavior serves to recognize the importance of behavior change in achieving meaningful scale-up and also to house HWTS in the appropriate directorate within Ghana's complicated ministry set up. In discussing HWTS as a behavior, the Strategy and its supporting documents focus largely on its integration into other health and sanitation efforts, namely safe excreta disposal and hand washing with soap, and, specifically the development and integration of IEC materials for behavior change communication. Pairing this information with what I learned of the Strategy's dissemination and its anticipated impact on the responsibilities of local government staff, I anticipate that little change will come unless a more concerted effort is made to plan and carry out behavior change activities, including building the capacity of MMDA staff to lead local efforts.

Private Sector Participation

Although the Strategy and its supporting documents define HWTS as a behavior, the latter half of the overarching goal stated in the strategy hints at another emphasis, as the goal is to be achieved "through the use of appropriate technologies." And who, we might ask, will be producing and distributing these technologies? The answer is: the private sector. In short, the state is taking responsibility for behavior change, but not for the crucial infrastructure on which these behaviors are to be practiced.

Defining HWTS as a behavior is a key point within the Strategy; however, more content in these documents is dedicated to private sector participation, and it is clear that this is to be the true priority in the scale-up of HWTS. For example, two of the three pillars of the implementation model are built upon private sector participation: public private partnerships and the commercial/business approach. Furthermore, one of the supporting documents is dedicated to the Private Sector Participation Framework. It is clear that those who developed the Strategy and its supporting documents fully bought into the argument that Clasen 2009 so clearly set forth regarding the private sector's potential role in scaling up HWTS: "The private sector is one obvious partner; it possesses not only much of this expertise but also the incentive and resources to develop the products, campaigns and delivery models for creating and meeting demand on a large scale."[465]

Initially, it seemed that the HWTS producers in Ghana agreed, as both Vestergaard and PHW were involved in the strategy development process. But as we saw earlier, Ms. Annan of Vestergaard was skeptical regarding the high expectations for the private sector's involvement and commitment, and Ms. Jackson of PHW expressed doubt that the finalized Strategy would have an impact on PHW's everyday operations. Although not involved in the strategy development process, Ms. Devroy of Ghanapreneurs was also doubtful that the strategy would have an impact. In the previous chapter, we also learned of the challenges that Vestergaard, Ghanapreneurs and Ceramic Tamakloe had in achieving scale-up through a commercial approach. PHW had achieved some success in direct sales, but these sales still only represented 20% of all sales, and reaching this level of success had taken almost 10 years. Both PHW and Ceramica Tamakloe's biggest buyer had been UNICEF, mostly for emergency response efforts. Furthermore, PHW's direct sales and product development efforts were focused on urban, middle-class consumers, not on the rural poor that they served with free, blanket distributions of filters.

The urban middle class is where the incentive exists, whereas HWTS producers like PHW don't see an economic incentive involving consumers at the bottom of the pyramid. This is a riskier and more challenging market. Even if the demand exists, it is unlikely to be what economists call *effective demand* – that is, demand backed by ability to pay. Poor, vulnerable populations are typically rural and therefore more difficult to access, and, by nature of their poverty, have less disposable income to spend on HWTS products. And, in fact, demand for HWTS has yet to fully materialize in Ghana, as was found in both the 2010 assessment by consultant Marion Kyuomuhendo for UNICEF and the 2015 rapid market by consultant Roshini George for the WHO.

In short, contrary to the heavy focus on private sector participation and commercialization, the market to incentivize private sector entry into HWTS does not exist. As we saw with Ceramica Tamakloe, the lack of demand for HWTS in Ghana has essentially led to the exit of this company from the market. Thus far, attempts to commercialize HWTS in Ghana have largely failed.

Let us explore two significant challenges to successful private sector participation - regulation and financing - and how the strategy addresses them. We'll also look briefly at subsidies and competition in this section as well.

Regulation

Earlier, I presented reflections from HWTS stakeholders on the lack of clarity with regards to certification and regulation of HWTS products in Ghana. These reflections highlighted two different positions from which stakeholders are trying to navigate this uncertainty. The first was a position of self-interest with regards to inspiring consumer trust in an HWTS product; the second was a position of confusion and concern over potential legal ramifications of failing to achieve a certain performance level. Both instances occurred before the finalized Strategy was circulated, so let us now consider the content of the Strategy and its supporting documents and explore whether or not these documents help to address the uncertainty around regulation of HWTS in Ghana.

In a section on creating an enabling environment for HWTS, the Strategy states simply that the development of national standards for HWTS product assessment will use as references the best practice guidelines of both the FDA and the GSA as well as those of the Metropolitan, Municipal and District Assemblies (MMDAs). Further on, in the Roles and Responsibilities section, the GSA is designated as the regulatory body responsible for developing these national standards. There is no further discussion as to the specifics of these standards, how they will be enforced, or what the repercussions will be if a product fails to meet them.[466] There is no discussion of certification and regulation in the Scale-up Model.

In the PSP Framework, however, there is also a section on creating an enabling environment for HWTS, which again includes development of national standards in line with FDA, GSA and MMDA guidelines. It goes further than the Strategy in that it specifies that these standards will also be in line with global best practices, but it does not identify what these global best practices are or may be. This section goes on to say, "The government will create a certification and product labeling system so that consumers can make informed decisions and choices in acquiring new HWTS products."[467]

Later on, several more sentences are dedicated to registration and certification under "Implementation Arrangements." Here, the PSP Framework states that certification according to standards approved by the International Organization for Standardization is required, as well as endorsement by the GSA FDA. In addition to certification for performance, this section states that product appropriateness should be evaluated, using the WASHTech Technology Applicability Framework (TAF) as the minimum standard.[468]

The TAF was created as a part of the broader WASHTech project, which was carried out over three years by a consortium of organizations and institutions, including IRC International Water and Sanitation Centre, Cranfield University and WaterAid (UK, Ghana, Burkina Faso and Uganda). It is a decision-making support tool for evaluating the applicability, scalability and sustainability of a WASH technology when considering its potential for use and scale-up.[469]

Given both the lack of detail on certification and regulation and the conflicting information within what information is provided in the finalized strategy and supporting documents, it is not surprising, then, that confusion over this critical next step persisted in Ghana after the dissemination of the Strategy and its supporting documents. In 2015, Roshini George, a consultant for the WHO, performed HWT market assessments in Ghana, Ethiopia and Vietnam that aimed to characterize the regulatory environment and current status of HWT products in these countries. In an interview, she said that, at the time of her visit to Ghana, it was still informally accepted that chemicals such as chlorine would be tested by the FDA and filters would go to the GSA but that this understanding was not formally established in a law or legislative instrument. As such, testing of filters by the GSA remains a voluntary decision by producers, as it was for Beth Devroy three years prior.[470]

Why does such confusion persist? To my knowledge, representatives from the GSA and FDA were not present at the West Africa Regional Workshop nor at the meeting of the HWTS Technical Working Group I attended in Fall 2012. However, Mr. Quansah of EHSD-MLGRD informed me that both the GSA and FDA had representatives as members of the larger HWTS working group. This larger group provided input to the core members who served on the smaller Technical Working Group and met more frequently to develop the strategy.[471] Further, Mr. Quansah informed me that a representative of the Ghanaian GSA was present at a WHO-hosted HWTS strategic meeting in Geneva in March 2015, which included a debriefing on the findings of the market assessment and a review of and discussion on the application of the WHO Evaluation Scheme.

If bringing the GSA and FDA to the table is not enough, what next steps can be taken to clearly establish the roles of each in HWTS certification and regulation? How can the GSA and FDA be more effectively engaged to better establish their roles and their capacity to fulfill these roles? What are the impressions of the general public as to whether certification from such entities bears weight and is trustworthy? It is clear that the mention of the GSA and FDA in the HWTS strategy and supporting documents does not provide enough detail regarding their roles nor does it provide them with any clout by which to strengthen their regulatory role and enforce standards.

Clarification of the roles of the GSA and FDA is not the only major hurdle to overcome in achieving effective certification and regulation of HWT products. Another significant hurdle is the determination of the standards/criteria by which technologies will be evaluated. Beyond determining a technology's appropriateness, it will be necessary to determine its efficacy in removal of microbiological contaminants. In Ghana, as in many countries, HWT-specific standards do not currently exist, so when products are tested, they are tested according to the national drinking water guidelines. In Ghana, this means that products must achieve the zero E. coli standard, which is not consistently attainable by many HWTS products. It is possible that the WHO International Scheme to Evaluate Household Water Treatment Products could be put to use here. We'll explore this possibility later.

Financing

When asked what the biggest challenge would be to rolling out the Strategy and scaling up HWTS, Ms. Jackson of PHW and Ms. Annan of Vestergaard responded with the same word: funding. Beyond that, they also both pointed to UNICEF as the source of what little funding they anticipated being disbursed for these efforts.[472,473] Ms. Jackson was of the opinion that things would only move forward around HWTS if UNICEF had the money because there were too many other demands on the Government of Ghana's money, so she didn't anticipate the Government contributing significantly. She hoped, though, that the Government would get behind a big public awareness campaign focused on introducing HWTS and its importance and throwing the Government's support behind HWTS so that others could follow suit. She anticipated that such an endeavor on a national scale would not only require political will but also a significant amount of money and stated bluntly, "That's something that manufacturers can't afford because it's very expensive. We don't have the money."[474]

Ms. Annan anticipated UNICEF contributing seed money, but she got the sense that the organization was also hoping that other development partners would join, even though any such developments were thus far slow in coming. Like Ms. Jackson, she saw a great need for government commitment of not only political will but also funding. Here, she went farther to also consider the role of civil society, mentioning the possibility of citizens volunteering to help with distribution and training.[475] Regardless of who was contributing what time and resources, it was clear that these endeavors would be expensive and that the means to fund them had yet to materialize.

The Strategy speaks directly of the need for funding. One of the seven thematic areas is Financing and Partnerships, under which the two strategic actions are: (1) secure the financial support needed to implement HWTS; and (2) engage the private sector. Under the first strategic action, the Government, development partners and the private sector are recognized as having funding HWTS activities thus far. The objective is to strengthen the existing sources of funding and seek out new funding, particularly through engaging micro-finance institutions (MFIs).[476] The hope is to mobilize resources to "finance the implementation of all the components of the HWTS strategy and priority actions,"[477] although a specific section is dedicated to securing funding specifically for a seemingly random list, including: training, institutional capacity building, developing BCC strategies and materials, developing products for emergency response, and performing research and monitoring and evaluation.

Research is again emphasized in the second strategic action focused on engaging the private sector, which focuses on collaboration between the private sector and universities, with the private sector investing in research, development and distribution of HWTS products. Unfortunately, a budget is not provided within the strategy. The Ministry of Finance is to take on the responsibility of preparing and obtaining approval of the budget, as well as providing the allocated budget amounts to the assigned recipients in a timely manner and supporting the Government in securing financing for the Strategy's implementation.[478]

In the Private Sector Participation Framework, financing is only listed as a responsibility of the private sector and not as one of the public sector as well. Given that reliable sources of funding have yet to be identified and developed, this would do little to allay Ms. Annan's fears of the high expectations for private sector commitment, particularly with respect to the commitment of funds. Reading further, however, one learns that the private sector is expected to avoid direct subsidization of products by working with MFIs to develop and implement new financing mechanisms or by making use of existing credit schemes to support HWTS uptake.[479]

In Ghana, there are a range of MFIs, including those run by rural and community banks and by savings and loans companies. NGOs are also involved in micro-finance and have been critical in extending these services into the poorer northern regions of Ghana. The micro-finance schemes run by NGOs focus on income-generating activities and generally do not require collateral. Some of these schemes may also incorporate health-related activities, but these activities are often in the form of education and are not the main focus of the loans. For example, a program "for" nutrition in Ghana didn't provide loans aimed at directly addressing nutrition but rather aimed at generating income that would make it possible for women to improve household nutrition.[480]

Engaging MFIs to provide loans for the purchase of HWTS products is likely to encounter a similar challenge to that of nutrition. Although HWTS may save money by reducing illness, which in turn reduces medical expenses and increases productivity, HWTS products are not revenue generating, as is also the case with nutrition initiatives such as the one mentioned above.[481] Further, a 2013 case study on MFIs in Ghana by the WHO found: "The MFIs that have been introduced and that integrate health appear to have largely been initiated by external NGOs… bringing charity funding to support social programs."[482]

In sum, although the Strategy and the Private Sector Participation Framework rely heavily on the participation of MFIs to provide loans for HWTS products as a new means of funding, there is not a precedent in Ghana for the provision of loans for non-revenue generating activities. Further, the private sector does not appear to have been engaged thus in MFI schemes that involved health-related initiatives. As a result, a lot of time and effort will first have to be committed to engaging MFIs and the private sector with the hopes of shifting their perspective on the value of providing loans for non-revenue-generating HWTS products. Traditional sources of funding such as the Government of Ghana and development partners will have to be relied upon in the immediate term. It is unclear, though, whether these traditional sources are willing and able to provide any significant amount of funding for HWTS efforts in Ghana beyond the seed money provided by UNICEF.

Subsidies

We learned in the last chapter that willingness to pay (WTP) for ceramic pot filters was approximately one tenth of the true selling price of PHW's filters.[483],[484] Furthermore, there is anecdotal evidence from PHW and others with experience in Ghana regarding a general lack of willingness to pay any amount given that HWTS products are often distributed for free.[485,486] Low willingness to pay for water quality, whatever the reason, is not unique to Ghana. A 2010 review of trials on household water access and water quality in developing countries found that many individuals had a low WTP for better quality water. This review applied a public economics framework to interpret the results of the trials being reviewed and concluded that subsidizing water treatment was "likely warranted" given the findings.[487]

One argument behind this conclusion was that water treatment, by reducing infectious disease, can have a positive health externality, and therefore, based on public finance theory, it may be appropriate to use subsidies to promote the use of water treatment. Furthermore, those most likely to benefit from water treatment - i.e. children under 5 years of age - do not have decision making power around household spending, and there is not much evidence that households with young children highly value clean water, making the potential welfare benefits from subsidized water treatment products even greater for them. The review also points to different behavioral biases that may keep households from "making decisions that maximize their welfare."[488] Based on these and other reasons and the findings from the trials, the authors argued that subsidies for water treatment should be considered.

A similar conclusion was reached in a parallel sector for an intervention that often overlaps with HWTS - malaria prevention through the use of insecticide-treated bed nets. In fact, the WHO's official position is in favor of large-scale, free or highly-subsidized distribution of insecticide-treated bed nets, arguing that these nets "should be considered a public good for populations living in malaria-endemic areas."[489]

Although bed nets and their use differ from HWTS products, based on the WHO's position on bed nets as well as the conclusions from the review above, it would be a worthwhile line of future research to try to better understand the Government of Ghana's position against subsidizing HWTS products. It is possible that this is a carry-over from Community Led Total Sanitation efforts, as one of the central concepts of CLTS is that it relies on no external subsidy for latrine construction in communities.[490] I did not explore the history behind this decision further during my field work, but I think that understanding this decision would be critical to deciding whether to pursue HWTS scale-up without subsidization or whether to reconsider incorporating subsidies, at least for certain populations.

Competition: Sachets

As discussed earlier, private sector participation is anticipated due to the (yet to materialize) profitability incentive, which will encourage market entry, leading to competition that lowers prices, improves quality, spurs innovation and increases product availability. Although the Strategy touches on competition within the HWTS market, it does not take the time to consider competition from the outside. In failing to do so, the Strategy ignores the elephant in the room: sachets. Sachets are sealed, 500mL plastic bags filled with drinking water that are often sold cold and by vendors in the streets of urban centers and in convenience stores, among many other places. They can be bought individually or in bulk. Interestingly, they are commonly called "pure water" instead of sachets. They are ubiquitous in urban areas and are seen as affordable, easy and safe.[491]

Although sachets are perceived as containing higher quality water than what can be obtained from the tap, most sachets in Greater Accra contain water treated and supplied by Ghana Water Company Limited's (GWCL) municipal system, and sachet producers are legitimate users of the system, paying GWCL for the water they use. With respect to the quality of sachet water, studies have found that the microbiological and chemical quality of sachet water ranges widely.[492,493] This variability could be due in part to the potential exposure of sachets to direct sunlight before consumption, as higher temperatures would encourage the growth of bacteria and may lead to the release of chemical contaminants from the plastic bag.

In spite of these concerns over water quality, some see sachets as filling "an important gap in household water security," arguing that the sachet industry "effectively extends improved water coverage deeper into informal settlements and slums, and alleviates the need in those places for a method of safely storing drinking water."[494] Although sachets were first adopted by the wealthy, they are now more likely to be associated with the urban poor. Regardless of the consumer, there is clearly a demand for sachets in Ghana, and the industry is booming: it is estimated that there are more than 2,700 sachet producers in Ghana, 99% of which are local.[495] With this rapid growth has come the challenge of regulation and certification. Although sachet producers are supposed to be certified before they begin production, this process is effectively being treated as optional by producers, with some intentionally ignoring the requirement and others simply unaware of it. [496] What can be learned from the sachet industry?

The 2010 assessment on the status of HWTS in Ghana touched briefly on sachet water as an alternative (lesser) water source given the lack of safe drinking water: "Consequently, households without access to clean water are forced to use less reliable and hygienic sources like dugouts, dams, hand dug wells and in some cases, especially the urban poor, unsafe sachet water, and often pay more for this sachet water." The report noted the increase in reliance on sachets as a primary drinking water source in Ghana over the past decade and predicted continued growth.

This acknowledgement of the sachet industry and potential competition to HWTS was not carried over into the Strategy and its supporting documents, which I think was a big oversight, as the sector stands to learn from the rapid scale up of sachets and attempts to certify and regulate sachet production. Arguably, sachets have moved the sector forward in making treated water readily available to the masses in a convenient, attractive form. Further, sachets have proven to reach scale rapidly with the entry of many different competitors into the market. In sum, sachets have done what those supporting HWTS have long dreamt of: improved quality of drinking water available, achieved commercialization, and rapidly reached scale.

However, with these successes have come challenges. In addition to variable water quality, there are concerns over whether all sachet producers meet the safety standards, maintain hygienic conditions when producing sachets, and use an appropriate source of water for filling sachets.[497] As a consumable product, sachets fall under the Food and Drug Authority's (FDA) jurisdiction.[498] Sachet producers are required by law to register with the FDA, which has enforcement authority, but a number of factors have made registration and certification by sachet producers essentially voluntary. The sachet industry has boomed thanks to low barriers to entry and the ability to turn a quick profit, which has encouraged wholesaling - the outsourcing of all production - and the entry of small producers to the market. This rapid addition of producers means that neither government agencies nor industry groups can account for all producers. It is believed that several hundred producers are unregistered. Further complicating the inability to keep track of all producers is the fact that it is also more difficult to be in contact with producers and share knowledge of registration requirements, which the FDA does through training sessions.[499]

Because HWTS is scaling up much more slowly, with only a handful of technologies being implemented and even fewer being produced in Ghana, in the short term, it would conceivably be easier to track the entry of new players and register and regulate existing HWTS products. As discussed previously, however, even now regulation and certification of HWTS products in Ghana is confusing. If Ghana continues to aspire toward the commercialization of the sector, certification and regulation requirements should be carefully considered to ensure consumer safety while also not discouraging market entry. Once established, certification and regulation requirements need to be clearly and effectively communicated to all HWTS stakeholders and then fully enforced. This consideration of sachets and a return to the challenges of setting standards for HWTS and then enforcing certification and regulation brings us to the next topic of interest: the WHO International Scheme to Evaluate Household Water Treatment Technologies and how it may be of use in Ghana.

4.4 The WHO International Scheme to Evaluate HWT Technologies

4.4.1 Background

The WHO has been a key supporter of HWTS for many years now. Specifically, the International Network to Promote HWTS (the Network) is at the center of all major HWTS activities. It was established by the WHO in 2003 with the following as its mission: “To contribute to a significant reduction in water-borne and water-related vector-borne diseases, especially among vulnerable populations, by promoting household water treatment and safe storage as a key component of community-targeted environmental health programs.”[500] In 2011, the Network established several targets, including a policy-based target intended to support HWTS scale-up and accelerate policy efforts in developing countries. The first half of this chapter was dedicated to the result of this policy support in Ghana: the Strategy and its supporting documents.

In addition to supporting policy development, the Network has also initiated research, including a global survey on HWTS policies in 2012 and a rapid market assessment of HWTS in 2015.[501,502] As discussed in the previous chapter, the main intent of the rapid market assessment, which was carried out in Ethiopia, Ghana and Vietnam, was to identify the HWTS products currently on the market, but it also investigated the regulatory environments in the three countries to better understand the context in which these products were being distributed and sold.[503] The focus here, however, will be on the WHO’s International Scheme to Evaluate Household Water Treatment Technologies (the Scheme), which was established in 2013, although its development began in 2009.[504,505]

Before looking at the scheme, I'd like to briefly review two documents that were published in the lead-up to the Scheme that were intended to support the evaluation of HWTS globally and that went on to inform the development of the Scheme itself:

- *Evaluating Household Water Treatment Options: Health-based Targets and Microbiological Performance Specifications* (2011)
    - Commissioned by the WHO
    - Authored by Professor Mark Sobsey (University of North Carolina) and Dr. Joe Brown (London School of Hygiene and Tropical Medicine)
- *A Toolkit for Monitoring and Evaluating Household Water Treatment and Safe Storage Programmes* (2012)
    - Commissioned by the WHO and UNICEF
    - Authored by Ranjiv Kush (Aquaya), Assistant Professor Daniele Lantagne (Tufts University) and Dr. Maggie Montgomery (WHO)

The 2011 WHO report introduced microbiological performance guidelines for evaluating HWTS products and also provided guidance on developing testing protocols to apply these performance targets. In doing so, the stated goal was "to inform implementers, protect users and encourage technology development by providing a risk-based framework to assess the performance of HWT interventions."[506] Furthermore, these guidelines and testing protocols could be incorporated into national or international HWTS evaluation programs. With respect to the performance targets, the authors used quantitative microbial risk assessment (QMRA) to develop at tiered system of health-based guidelines. The purpose of applying QMRA was to make use of available water quality data as well as exposure and dose-response models to make the link between microbiological contamination of drinking water and waterborne disease as clear as possible.[507] The result of this process was the tiered classification system shown in Figure 14 which we'll see show up again in the Scheme:

Target	Log_{10} reduction required: **Bacteria**	Log_{10} reduction required: **Viruses**	Log_{10} reduction required: **Protozoa**
Highly protective	≥ **4**	≥ **5**	≥ **4**
Protective	≥ **2**	≥ **3**	≥ **2**
*Interim**	Achieves "protective" target for two classes of pathogens and results in health gains		
Summary of performance requirements for small-scale and household drinking-water treatment, based on reference pathogens *Campylobacter jejuni*, *Cryptosporidium* and rotavirus (see Appendix 1).			

Figure 14. Health-based HWTS performance targets[508]

The 2012 WHO/UNICEF toolkit was intended to support the monitoring and evaluation (M&E) of HWTS and specifically of HWTS uptake, given the challenge of achieving correct, consistent use. The toolkit was developed in recognition of this challenge and also in recognition of the lack of consistency within the sector regarding the tools and indicators needed for effective M&E.

Included in the toolkit is a list of 20 recommended indicators that are broken down into the following groups: "reported and observed use; correct, consistent use and storage; knowledge and behavior; other environmental health interventions; and water quality."[509] A complete list of the 20 indicators can be seen in Figure X below. Although water quality is included among the indicators, the evaluation here is much more basic than that proposed for the risk-based performance targets and testing protocols. This makes sense, of course, given that the toolkit is intended for use in the field to capture a more holistic snapshot of HWTS, whereas the targets and testing protocols are intended for use in a highly controlled laboratory setting to capture the microbiological performance of HWTS products. We'll see later how the WHO struggles to keep this holistic approach in mind while largely focusing on laboratory evaluation of HWTS products in Round I of the Scheme.

Finally, although in the last chapter we heard from HWTS producers in Ghana about the confusion and concern on their end regarding certification and regulation and the need for clarification, we have not considered the needs on the users' end. The 2011 WHO report touches on this in its goal to protect users and, unfortunately, situations have arisen in which certification and regulation of HWTS was needed in order to protect users. For example, as part of emergency response to the earthquake in Haiti the country was flooded with HWTS products, and the government was swamped by companies seeking approval to distribute their products in Haiti.

As a result, in 2013, the Ministry of Health in Haiti requested technical assistance from Tufts University (Assistant Professor Daniele Lantagne and her PhD student Anna Murray) and the U.S. CDC to develop a national HWT product certification process. When four of the products seeking approval in Haiti were taken through the validation stage of the certification process, it was found that the manufacturers had provided information that was not applicable to household water treatment, did not demonstrate product microbiological performance, and was insufficient to ensure that the products were used safely. In the article published on this evaluation, Murray et al. concluded: "Products should be internationally assessed against WHO performance targets and also locally approved, considering language, culture and usability, to ensure effective HWT." In short, an international evaluation scheme was still needed to evaluate the microbiological performance of HWTS products and ensure user safety.

4.4.2 The Scheme

The Basics

In developing the Scheme, the WHO aimed to address this need by creating a set of criteria and testing guidelines that would allow for objective, independent and consistent testing of HWTS products. The result of the WHO's efforts was a set of performance targets and an evaluation procedure. The microbiological performance guidelines were taken directly from tiered system developed by Brown and Sobsey for the 2011, report, with the main change being a replacement of "highly protective," "protective," and "interim" with a neutral, three star performance classification.[510] You can see the performance criteria for the Scheme in Figure 15 below and refer to Figure 14 for comparison.

Performance classification	Bacteria ($\log_{10}$ reduction required)	Viruses ($\log_{10}$ reduction required)	Protozoa ($\log_{10}$ reduction required)	Interpretation (assuming correct and consistent use)
★★★	≥ 4	≥ 5	≥ 4	Comprehensive protection (very high pathogen removal)
★★	≥ 2	≥ 3	≥ 2	Comprehensive protection (high pathogen removal)
★	Meets at least 2-star (★★) criteria for two classes of pathogens			Targeted protection
–	Fails to meet WHO performance criteria			Little or no protection

Figure 15. WHO microbiological performance targets for HWTS products[511]

The evaluation procedure (See Figure 16) begins with an expression of interest (EOI) from a product manufacturer and prioritizes products that are low-cost, context-appropriate, freestanding and small-scale. After a screening of EOI's from manufacturers, the next step is a review of the existing data, testing procedures and testing laboratories to determine whether they meet the Scheme's requirements. This review determines whether full laboratory testing is required or whether there is sufficient, high-quality data to allow for abbreviated testing or even just an in-depth desk review of the existing data. The product is then tested accordingly following a harmonized testing protocol, which is intended to make sure that the evaluation is consistent across products but also appropriate for a given product. Testing is performed by one of two WHO-designated laboratories: KWR Watercycle Research Institute (Netherlands) and NSF International (United States). These two laboratories are those that were found to have the systems and technical capacity required for the testing protocols and for complying with International Organization of Standardization (ISO) 17025, which looks at testing and calibration competencies as well as quality assurance procedures. After testing, the WHO reviews the results and shares them with the manufacturer for comment.[512] Then, the results are published and disseminated, which brings us to the results from Round I of testing.

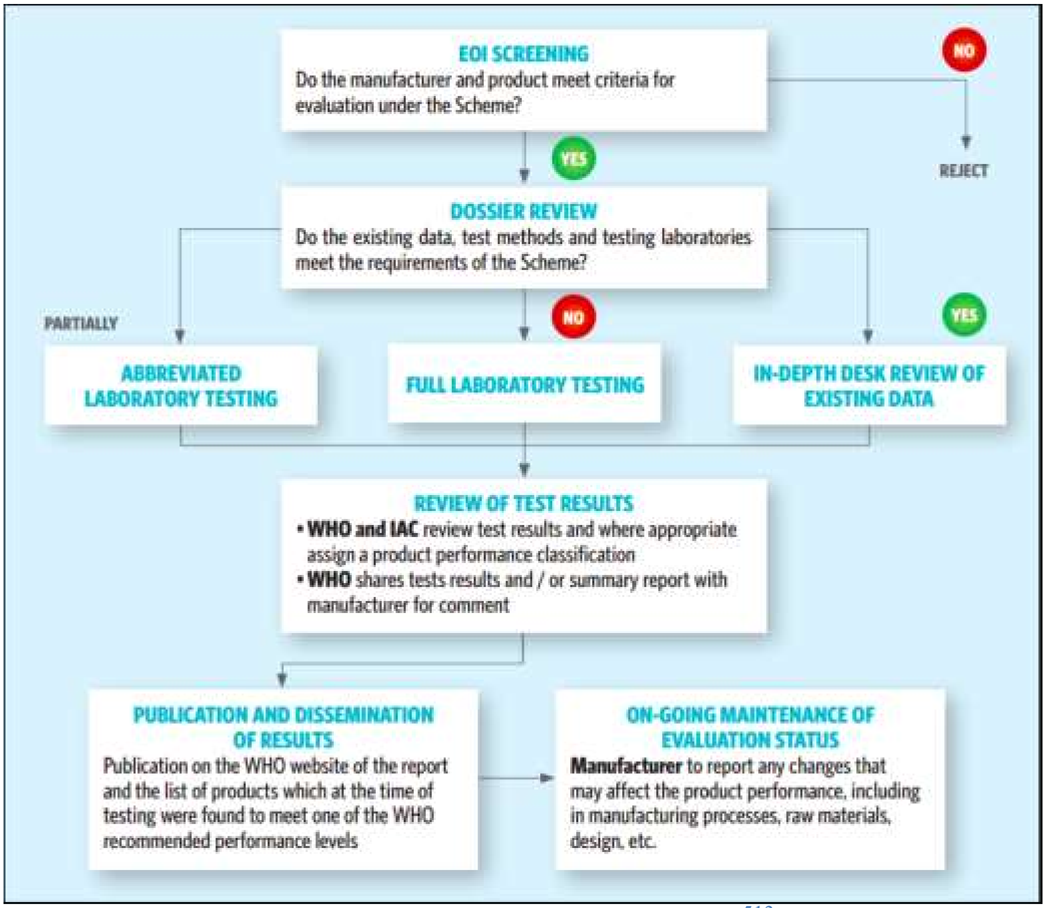


Figure 16. The Scheme's evaluation procedure[513]

Round I Results

After establishing the Scheme in 2013, the WHO sent out the first call for EOIs from HWTS product manufacturers in spring 2014. In response to this call, 26 manufacturers submitted 29 products for consideration. The initial screening process found that 12 of the submitted products did not meet the eligibility criteria. Additionally, seven products were withdrawn by manufacturers for a variety of reasons, including product readiness and the cost of testing. The remaining ten products continued the Round I evaluation process, with six undergoing the full laboratory testing procedures and four undergoing the abbreviated procedures.[514] These products, which represent a range of different treatment technologies, can be seen in Figure 17 below.

Technology	Product	Manufacturer	Evaluation procedure
Membrane ultrafiltration	LifeStraw Family 1.0	LifeStraw SA	Abbreviated procedure: Desk review of existing data
Membrane ultrafiltration	LifeStraw Family 2.0		Full laboratory testing
Membrane ultrafiltration	LifeStraw Community		Full laboratory testing
Ceramic filtration	TEMBO Filter Pot	Upendo Women's Group MSABI	Full laboratory testing
Flocculation-disinfection	P&G Purifier of Water	The Procter & Gamble Company	Abbreviated procedure: Desk review of existing data
UV disinfection	Waterlogic Hybrid / Edge Purifier	Qingdao Waterlogic Manufacturing Company	Full laboratory testing
Solar disinfection	WADI	Helioz GmbH	Full laboratory testing
Chemical disinfection	H2gO Purifier	Aqua Research LLC	Abbreviated procedure: Desk review of existing data
Chemical disinfection	Aquatabs	Medentech Limited	Abbreviated laboratory testing and desk review of existing data
Chemical disinfection	Silverdyne	World Health Alliance International Inc.	Full laboratory testing

Figure 17. Round I products[515]

The report on the results of this testing was published in spring 2016. For each of the technologies represented - membrane ultrafiltration, ceramic filtration, flocculation disinfection, UV disinfection, solar disinfection and chemical disinfection - the report on the results of Round I provides a technology description, a summary of microbial performance, technology advantages and limitations, and recommendations for appropriate application and context. Then, within each technology, each of the associated products (e.g. LifeStraw Family 1.0, LifeStraw Family 2.0 and LifeStraw Community for membrane ultrafiltration) are then presented individually, including the country/ies of manufacture, a product description, product specifications (i.e. power requirements, maintenance, lifespan, other features, and number of units distributed in 2013/2014), and a summary of the product's evaluation under the Scheme. In the body of the report, these technology and product summaries are presented before the results of the microbiological testing under the Scheme, which seems to be an intentional decision to try to emphasize the importance of considering all aspects of a product, not just microbiological performance.[516] The classification of products according to the tiered scheme are, however, presented in the Executive Summary as they are seen in Figure 18 below.

Technology	Product	Manufacturer	Performance target met	Performance classification (assuming correct and consistent use)
Membrane ultrafiltration	LifeStraw Family 1.0	LifeStraw SA	★★★	Comprehensive protection: *very high removal of bacteria, viruses and protozoa*
Membrane ultrafiltration	LifeStraw Community	LifeStraw SA	★★★	
Membrane ultrafiltration	LifeStraw Family 2.0	LifeStraw SA	★★	Comprehensive protection: *high removal of bacteria, viruses and protozoa*
Flocculation-disinfection	P&G Purifier of Water	The Procter & Gamble Company	★★	
UV disinfection	Waterlogic Hybrid / Edge Purifier	Qingdao Waterlogic Manufacturing Company	★★	
Chemical disinfection	Aquatabs	Medentech Limited	★	Targeted protection: *high removal of bacteria and viruses; no/limited removal of protozoa*
Chemical disinfection	H2gO Purifier	Aqua Research LLC	★	
Solar disinfection	WADI	Helioz GmbH	★	Targeted protection: *high removal of bacteria and protozoa; some removal of viruses*

★★★: removes at least 4 log_{10} of bacteria, at least 5 log_{10} of viruses and at least 4 log_{10} of protozoa
★★: removes at least 2 log_{10} of bacteria, at least 3 log_{10} of viruses and at least 2 log_{10} of protozoa
★: meets the performance targets for at least 2-star (★★) for *only two* classes of pathogens

Figure 18. Round I classification of products according to WHO performance criteria[517]

The Tembo Filter Pot and Silverdyne are absent from this table for different reasons. Testing on the Tembo Filter Pot was stopped before it was completed because the filter's flow rate was less than 0.5L hour, meaning that it took more than 24 hours to filter an 8L sample. This low flow rate conflicted with the manufacturer-provided average flow rate range of 1-5L/hour. The evaluation of Sylverdyne was completed, but the product failed to meet the requirements for one star/targeted protection. The results of testing for each product and each pathogen type (i.e. bacteria, viruses and protozoa) are presented in the body of the report in a format that I find to be much more informative (See Figure 19, below). Frustratingly, however, nowhere in the report can one find the actual performance numbers. You can see in the graph below that the removals achieved are rounded to a whole number for each log removal, and the graph is confusing labeled "Log10 reduction of bacteria, viruses and protozoa met or exceeded by products evaluated in Round I."[518] In trying to simplify presentation of the results, the authors failed to clearly and fully present these results.

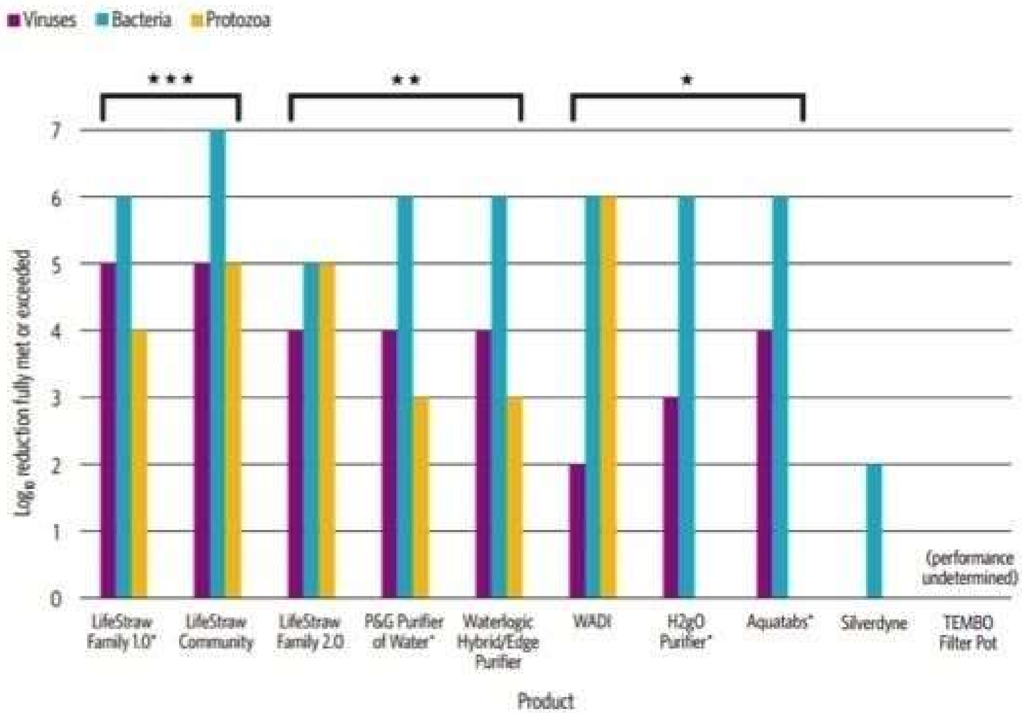


Figure 19. Product performance (Log10 reduction) by pathogen type[519]

In addition to the technology and product overviews and the results of product performance testing, the report also highlights other key findings. With respect to the review of manufacturer-provided product information and the existing data on product performance, the WHO encountered issues similar to those presented by Murray et al. from Haiti. Often, manufacturer testing could not support performance claims because testing failed to cover all three pathogen types. Furthermore, the existing data often comes from testing under ideal conditions as opposed to conditions that represent actual use under field conditions. And finally, the WHO found that products were often not labelled clearly and had confusing instructions for use, which could lead to incorrect use.

Another important finding was that the performance of a specific product can vary a lot between different units. This variation in performance among different units of the same product hinted at issues with quality control and assurance during manufacturing. An additional, related finding was that quality assurance and control in locally manufactured products like the Tembo Filter Pot would need to receive special attention. Such quality assurance and control issues affect biosand filter production as well, and the implications of these findings for ceramic pot filter and biosand filter manufacturers will be discussed in a later section.

In presenting the results of Round I, the report reiterated some of the key points communicated by the WHO when the Scheme was established. The first of these points is that the target need being addressed is the limited capacity within developing countries to test HWTS products and verify manufacturer claims. Second, the target audience for the Scheme consists of UN Member States and procuring UN Agencies. And finally, the objectives of the Scheme are to support governments in evaluating HWTS products and to provide independent, consistent testing to support the target audience in selecting HWTS products. Importantly, the report for Round I makes it clear what the Scheme and its results are NOT intended as:

- An endorsement or certification by the WHO;
- A product approval from the WHO, as national authorities remain responsible for granting approval; or
- An implication of performance for products not mentioned in the report.

Overall, the report on the results of Round I is a clear, concise, carefully-worded document that aims to present the findings in an unambiguous, unbiased manner. The context in which Round I was carried out, however, remains complex and uncertain.

Reactions to the Scheme

This uncertainty was made clear at the October 2014 UNC Water and Health: Where Science Meets Policy. The presentation of the scheme at the Annual Meeting of the International Network for HWTS and the questions that followed focused mostly on logistics and cost of testing, both of which are not insignificant obstacles, particularly for small-scale, local manufacturers. Imagine, for example, trying to get a ceramic pot filter or a concrete biosand filter from a country in Sub-Saharan Africa to the Netherlands for testing. As for the cost of testing, it is estimated to range from US$25,000-40,000, although the WHO may offer to waive some of the cost for some applicants, depending on the availability of funds.

Discussion of the Scheme continued in the side events on ceramic pot filters and biosand filters at the conference. Concern over failure to meet the lowest level of treatment laid out in the scheme was a central topic at these side events. In "Biosand Filters: Defining Future Research Directions for Greater Impacts," the consensus was that the BSF will very likely not pass the WHO scheme evaluation, which led to questions and concerns over the potential impact on funding for and implementation of BSFs. In "Ceramic Pot Filters: Current Research, Future Directions and Defining Next Steps," one prominent researcher expressed the opinion that the development of the WHO scheme had gone "off the rails" with regards to the performance requirements.

Another topic of discussion was the challenge of quality control and assurance. And in fact, the Ceramic Filter Manufacturing Working Group has for some time been working on its own certification scheme for ceramic filter factories (funded by the US Centers for Disease Control and Prevention) to improve quality control.[520] The evaluation protocol that has been developed in this process is seen as an example of a potential decentralized evaluation scheme that could be used in place of the WHO scheme. But this ceramic filter-specific scheme did not successfully address all of the concerns voiced with respect to the WHO scheme or the challenges faced by participants in the regional workshop in Ghana. To name a few, questions arose over whether to work with international or local certifying organizations, how to develop standards that ensured quality but were also feasible in countries with limited resources, what the cost of such certification would be and whether fees would be subsidized for producers who could not afford them.

Quality control is also a concern for the biosand filter. The WHO has been in communication with CAWST[r] regarding the development of a quality control process for decentralized biosand filter production and installation, not unlike that being produced for ceramic pot filters by the Ceramic Filter Manufacturing Working Group. CAWST's work on a quality control process was catalyzed by CAWST's position that the current harmonized testing protocol under the Scheme is more suitable for non-biological treatment processes and is not representative of how the biosand filter is used in real world situations.

[r] Although CAWST's services now cover a wide range of WASH interventions, the organization was originally founded to support biosand filter construction and implementation programs, and it remains a sector leader in this regard.

In the WHO 2011 *Evaluating HWT options: Health-based targets and microbiological performance specifications*, from which the tiered evaluation system came, the authors point to the Guidelines for Drinking Water Quality, which recommends the use of QMRA to evaluate risk and support decision making, especially when epidemiological data is not available. They go on to say: “Scientifically credible and methodologically rigorous performance data meeting the standards of peer-reviewed research should be used in establishing performance.”[521]

In the previous chapter, I briefly presented information from epidemiological evaluations of both the ceramic pot filter and the biosand filter. Clasen et al. 2015 estimated 61% and 53% reductions in diarrhea, respectively, and found the quality of evidence to be moderate. CAWST’s position is that the evidence on the biosand filter exceeds what is necessary to establish the performance of the filter. I am not similarly privy to the opinions of the Ceramic Manufacturing Working Group regarding the Scheme and the ceramic pot filter. I am made to wonder whether an emphasis on performance in the lab, even if under challenging conditions to simulate real world conditions, has been an accidental result of the use of the tiered system by the Scheme that comes at the cost of not considering other factors for a more holistic picture of the performance of HWTS products.

4.4.3 Discussion

Whether intentional or not, the reliance of the Scheme on the tiered system that evaluated HWTS products according to their microbiological performance may shift the focus of its target audience - the governments of WHO Member States and decision makers of UN procuring agencies - entirely to these criteria as opposed to a well-rounded consideration of a range of factors. Included among these other potential factors are ease of use, robustness, cost, maintenance requirements and lifespan, which also affect whether an HWTS product can be correctly, consistently and continuously used in order to reduce diarrheal disease.

To be clear, the report on the results of Round I recognizes the importance of such factors, saying in the Background section that there are two key requirements in order to achieve improved health through HWTS: "First, HWT technologies must be microbiologically effective… Second, such technologies must reach, and be consistently used by, the groups most at risk for waterborne disease. This requires consideration of a number of key factors such as effective supply chains, affordability, user preferences and changing and sustaining user behavior." The report also touches on such factors in the technology and product overviews and emphasizes use of the multi-barrier approach - combining technologies - as a way to achieve comprehensive protection. In this way, the WHO is clearly trying to encourage stakeholders to consider factors outside of microbiological performance.

In spite of these and other efforts in the report and in other WHO communications, the testing results from Round I have been the focus of any discussion on the Scheme in which I've observed or participated. At the UNC conference, both ceramic pot filter and biosand filter manufacturers and implementers worried over the impact that "failing" the scheme could have on their efforts, even if their filters are found to reduce diarrhea in field trials and are easy to use and low cost. Furthermore, the Scheme was specifically developed to fill a gap in local government capacity to evaluate

HWTS products. It is understandable that microbiological performance is a minimum requirement and a good place to start, but the WHO will have to continue to exert effort toward making the conversation about more than just the testing results.

The report also highlights the challenges of quality assurance and control of locally manufactured products. There seems to be no immediate solution to quality management that fits within the Scheme as opposed to outside of it like the efforts of the Ceramic Manufacturing Working Group and CAWST.

As mentioned in the previous section, another challenge to local manufacturer participation in the Scheme is the cost of testing, which is likely prohibitive to many small scale manufacturers that rely on inconsistent donor funding. Another challenge for local manufacturers, whose products are likely designed and produced with minimal travel in mind, is sending their product to one of the two designated laboratories in the Netherlands or the United States. Given the requirements for designation, it is highly unlikely that labs in developing countries will be able to perform testing of products under the Scheme. To the WHO's credit, the roll out of the Scheme includes capacity building activities to support local governments in strengthening regulation, assessing local products, and monitoring and evaluating HWTS.[522] To my knowledge, the capacity building activities held thus far have taken place in Ethiopia. The WHO is also working to make its testing protocols simpler and cheaper and to support developing countries in using similar protocols so that more products can be tested.

However, given that testing under the Scheme cannot currently be carried out in-country, is it assumed, then, that the Ghanaian government will rely on the results of the Scheme to determine whether or not to approve a HWTS product for use in country? Or is information from the Scheme to be used to supplement results of testing and certification in Ghana? Since neither the PHW ceramic pot filter nor Hydraid have been tested under the Scheme, how are they to be handled in the meantime? One can imagine it would be hard to not compare the lack of information on these two filters to the "success" of the LifeStraw Family 1.0 and 2.0 and the LifeStraw Community in achieving a three star rating under the Scheme. If the ceramic pot filter and Hydraid were tested under the scheme and found to achieve targeted protection (one star) or little or no protection (fail to meet the WHO performance criteria), what would the implications be for ongoing implementation efforts in country? For filters already implemented in households?

Given the ongoing involvement of the WHO in efforts around HWTS in Ghana, it is likely that it will work closely with the Ghanaian government to answer these questions and others as they arise and as the Scheme develops. In its current form, however, the Scheme does not effectively address the needs in Ghana around clarification of certification and regulation, both with respect to the performance requirements - Ghanaian EPA zero E. coli requirement or WHO performance criteria - and the testing entity - GSA, FDA or a WHO-designated laboratory.

Finally, in the report on the results of Round I, the WHO includes findings from the rapid market assessment and emphasizes the use of targeted market approaches to create an enabling environment that supports scaling up HWTS. In these explicit ways and in other subtler ways, commercialization of HWTS as a means of achieving scale-up is a part of the discussion within the report. However, in its current form, the Scheme actually supports the status quo of the HWTS sector as opposed to the creation of a diverse, competitive market that produces a wide variety of HWTS products appropriate for a range of users, contexts and incomes.

The stated target audience of the Scheme is WHO member states and UN procuring agencies. As a result, the communication of the results of testing under the Scheme are directed toward this target audience and in a way that is unlikely to lead to information at the user level. To achieve meaningful scale-up through commercialization would require a well-informed user-base that has the information needed to make informed decisions about HWTS products and their use. Instead, the discussion is often around protecting users as opposed to informing them. Furthermore, locally manufactured products face significant challenges under the Scheme. Ghana's National Strategy for HWTS emphasizes local production of HWTS products as a way to diversify the market and lower costs, but local producers are unlikely to enter the market if there is uncertainty around the Scheme and its implications for certification and regulation. Therefore, the Scheme further commits the sector to the status quo of NGOs using donor funding to purchase HWTS products and then performing blanket implementations that effectively eliminate consumer choice, with consumer choice being a critical argument for commercialization.

4.5 Conclusion

Where does that leave us, then? The Strategy and its supporting documents define HWTS as a behavior, thereby recognizing the importance of behavior change to achieving uptake and therefore improved health. This is a key step in considering a holistic approach to HWTS; however, based on how the Strategy has been rolled out thus far and how it is perceived by the local government staff as bringing little change to their current responsibilities, it is unlikely that defining HWTS as a behavior will lead to effective behavior change. While highlighting behavior change, the Strategy and its supporting documents also heavily emphasize private sector participation and the use of market strategies to scale-up HWTS in Ghana. Unfortunately, there does not yet seem to be sufficient demand in Ghana to create a market for HWTS that generates the profitability incentive required to encourage the entry of new HWTS manufacturers.

As it stands, efforts to scale-up ceramic pot filters, Hydraid and LifeStraw Family 1.0 have not been sufficiently successful to generate profits or even maybe to just support the continued existence of producers/implementers, as we saw in the case of Ghanapreneurs and Ceramica Tamakloe in the last chapter. In the instance of PHW's relative success in scaling up implementation of the AfriClay filter, this success was largely due to bulk purchases of the filters for emergency response. Blanket implementation of filters are essentially the opposite of commercialization. In the former, users are recipients of aid that do not have a choice and do not even necessarily express a demand for HWTS; in the ideal conception of the latter, users are consumers in a market where they make decisions based on available information and their priorities. Given the current state of HWTS in Ghana and considering how HWTS has been scaled up elsewhere, as in the case of P&G's Purifier of Water and Vestergaard's Carbon for Water campaign, the latter seems an unlikely future for Ghana.

Regardless of how HWTS is scaled up in Ghana, certification and regulation will be critical. However, confusion over certification and regulation remains a challenge to those currently producing and implementing HWTS in Ghana and is likely a further deterrent to those who might consider entering the market. The WHO Scheme has established a means of evaluating HWTS products on an international level, but the implications for local certification and regulation as well as current production and implementation in country are not yet clear. And finally, the financing needed to support the roll out of the Strategy and all of its strategic actions to support scaling up HWTS has yet to materialize, leaving HWTS stakeholders in Ghana skeptical as to the impact of the Strategy on their operations.

The Strategy and its supporting documents are ambitious in their scope and set out many key actions to supporting the scale-up of HWTS in Ghana. In this ambition and in the extensive list of things to be done, as well as in the elements that they fail to effectively address and clarify, these documents make it clear that the process of scaling-up HWTS in Ghana will not be achieved quickly and that the government cannot expect the private sector to resolve all of the current challenges through commercialization. If the decision is to continue with HWTS as a way to provide safe water to vulnerable populations, the long-term involvement and commitment of the government as well as donors, NGOs and the private sector will be needed to effectively roll out the Strategy and scale up HWTS. Given the commitment required, the emphasis should truly be on reaching vulnerable populations, realizing that commercialization efforts are likely to focus on and reach middle-income consumers, not the poorest of the poor.

5 Conclusion

5.1 Chapter Summaries

This dissertation was structured to mirror the three major targets set forth by the Network with regards to promoting the scale-up of HWTS. I summarize these targets simply as: research, practice and policy. Below, I review each of the targets and summarize the key findings and conclusions for each corresponding chapter, ending with a key quotation.

5.1.1 Research

"By 2015, more credible and convincing evidence demonstrates that HWTS interventions are effective and replicable in terms of achieving long-term, widespread use and public health impact."[523]

In Chapter 2, I explored the evidence base on HWTS that has been built up over the past couple of decades. Although the sector often looks to peer-reviewed, scientific publications for credible evidence, the grey literature also contributes significantly to the direction of the conversation and to the arguments made in support of HWTS. Establishing a credible and convincing base of evidence relies upon more than the four means to evaluate HWTS that are seen in the scientific literature, as it also depends upon the means by which the sector communicates these findings and the arguments they support. Furthermore, there are many actors involved in the generation and consumption of both the scientific and grey literature who, in turn, contribute to the broader conversation and activities around HWTS.

For Chapter 2, I established a sub-set of the literature on HWTS centered upon RCTs on HWTS. In establishing this collection, I defined a sub-conversation on HWTS that I could explore to better understand knowledge creation and sharing and its effects on the conversation around HWTS. After establishing this collection, I began with a simple textual analysis of the titles and abstracts of the 35 RCTs and 600 Citing Articles in the collection. Allowing for a delay from performing the research to publishing an article, the trends in which HWTS options were talked about and how over time reflected what I had perceived in my reading of the literature and participation in the sector over the past half dozen years.

The latter half of Chapter 2 focused on the most cited RCT publication, systematic review and meta-analysis, and grey literature publication. I encountered challenges with respect to identifying the most cited systematic review and meta-analysis because documentation and citation of the scientific literature was often unclear, making it difficult to track the connections between publications. I faced similar issues with respect to tracking the citations of grey literature, as it is not at all documented with unique identifiers. After identifying these three publications, an impact evaluation highlighted the differences between how scientific and grey literature are cited and used to support arguments, with the grey literature sometimes being cited in an incorrect or misleading way. This problematic way in which grey literature is sometimes cited is made even more problematic by the inconsistent way in which these citations are documented, often making it difficult to track the citation back to the original source. Finally, the argument for HWTS as an interim solution first emerged in this chapter in the foreword written by Jamie Bartram, then of the WHO. This emphasis would be seen and discussed in the subsequent chapters, as well.

"Effective measures are needed immediately to provide at risk populations with safer water at the household level until the long-term goal of providing safe, piped, community water supplies can be achieved. There is now conclusive evidence that simple, acceptable, low-cost interventions at the household… level are capable of dramatically improving the microbial quality of household stored water and reducing the risks of diarrheal disease and death in populations of all ages in the… developing world."

– Jamie Bartram[524]

5.1.2 Practice

"By 2020, 50 countries have achieved country-wide scale up of project-based HWTS."[525]

Chapter 3 investigated efforts to scale-up HWTS Ghana, focusing on three specific products: LifeStraw Family 1.0, the Hydraid biosand filter and the AfriClay filter. In spite of the differences between these products and their manufacturers and implementers, the attempts to bring them to scale shared two important goals: (1) reaching vulnerable populations; and (2) achieving scale through commercialization. The challenges and successes of these efforts highlighted conflicts of interest between the twin goals above. For HWTS, effective scale-up means achieving not only coverage but also uptake – HWTS must not only be made available but must also be used correctly and consistently by the target population.

Before exploring these efforts, we first learned from the means by which two for-profit companies achieved scale outside of Ghana. Neither the massive consumer product company Procter and Gamble nor the successful insecticide treated bed net giant Vestergaard achieved scale through their usual means, and especially not through commercialization. Furthermore, it is highly unlikely that the "scale" these two campaigns achieved actually met the ultimate goal of effective scale-up, which requires not only coverage but also uptake of the technology by the end user.

It was not a surprise, then, that efforts to scale up HWTS have encountered similar challenges. From the three product case studies, we learned that commercialization of HWTS in Ghana has seen minimal success, with what little success there is coming at the cost of reaching the most vulnerable populations first. In the instances in which relatively large-scale distribution of HWTS was achieved in Ghana, it was through blanket implementations that were funded externally. Chapter 3 ends with the conclusion that, if HWTS is to continue to be pursued in Ghana as an immediate means of safe water provision for vulnerable populations, efforts should be focused on this goal and not on commercialization.

> *"So you can take the filters and go and give it to everybody in the country? Think about it. There's no reason you can't. Think about it. Raise the money." – Peter Tamakloe*[526]

5.1.3 Policy

"By 2015, 30 countries have established policies on household water treatment and safe storage."[527]

Chapter 4 considered the results of the Network's efforts to establish HWTS as a policy by evaluating two sets of documents: (1) Ghana's 2014 National Strategy for HWTS (the Strategy) and its supporting documents; and (2) the WHO International Scheme to Evaluate Household Water Treatment Technologies (the Scheme) and the results of Round I. More specifically, I explored the content of these two sets of documents and evaluated whether they effectively support the scale-up of HWTS.

After reviewing the basic content of the Strategy and its supporting documents, I focused on the key points that were intended to facilitate scale-up of HWTS in Ghana: (1) defining HWTS as a behavior and (2) relying upon private sector participation. Defining HWTS as a behavior led HWTS efforts to be housed in the Environmental Health and Sanitation Directorate and integrated into existing sanitation and hygiene efforts. Because of minimal funding, no additional staff, limited dissemination and no anticipated changes in the everyday activities of local-level government staff, I concluded that defining HWTS as a behavior, although theoretically sound, would facilitate the continuation of the status quo as opposed to the wide promotion of HWTS. With regards to relying on participation from the private sector, I built upon the findings from Chapter 3 when discussing the challenges that Ghana faced with respect to regulation and certification of HWTS products, financing the roll out of the Strategy and the scale-up of HWTS, and avoiding subsidies. Unfortunately, the Strategy and its supporting documents did little to address these challenges or factor in the reality of the HWTS situation in Ghana with respect to these three aspects of private sector participation.

The second part of Chapter 4 focused on the WHO Scheme and the results of Round I of testing under the scheme. The Scheme was developed in response to a well-documented need to certify and regulate HWTS products at the national level but was also intended to support a more holistic approach to HWTS implementation that considers other factors critical to effective scale-up. In its current form, however, the Scheme's evaluation process as it was applied to 10 products in Round I largely focused on pathogen inactivation or removal, based on a tiered system of microbiological performance targets. After reviewing the current version of the Scheme, the results of Round I, and feedback from the sector, I concluded that the Scheme faces significant obstacles with respect to helping countries such as Ghana achieve effective certification and regulation and support local development and production of HWTS solutions. Furthermore, although it conceptually supports commercialization, in practice, its current form supports maintaining the status quo of external funding for blanket implementation of HWTS.

"The model for operationalizing the national strategy… is anchored around three (3) interdependent approaches: (i) 'behaviour- first' approach (ii) public private partnership; and (iii) commercial/business approach. These approaches are currently being used for Safe Excreta Disposal (SED) and Hand-washing with soap (HWWS) interventions. HWTS implementation will dovetail within and build on these and other related strategies and national policies currently being implemented in Ghana in an integrated approach rather than a stand-alone programme."[528]

5.2 Overarching Conclusions

In writing the final parts of this dissertation, I came across an interview in which the respondent, Michael Steene Lunde of Vestergaard, so honestly and bluntly articulated the challenges of HWTS that, if I had realized it at the time, I could have closed up shop and moved on to the next problem:

> "The ideal solution is they would just open the tap and clean water comes out. Are we there yet? No. Is that going to take a while? Yes. So what do we do in between? Do we go this route of HWTS, and if we do, that's going to cost a lot of money. It's going to cost a LOT of money. And it's so much money that you're almost tempted to say, 'Oh, let's go back and dig some boreholes or do some infrastructure. Better pictures in the paper. Moving up the ranking of countries, access to water. Millennium Development Goals and what have you'… If you want to get private companies involved, they don't like something fluid. They want something tangible. And we don't have that. And I think that is a huge impediment to any funds flowing. But not only is it… bad for our business, but it's also bad for people because you don't get… movement either on infrastructure or on this. It's kind of like we don't know what to do, so we'll just park it over here and pray."[529]

Unfortunately for you, dear reader, that was not the case. But as luck would have it, we've reached the end.

In Chapters 2, 3 and 4, the argument for HWTS as an interim solution that can rapidly reach scale repeatedly emerged, creating a common thread throughout the dissertation. However interim, or immediate, or quickly, or whatever word is used in a particular moment to contrast the time and effort required to achieve the "long-term" goal of centrally treated, piped water, is never clearly defined. How long is this intervening period supposed to last? How temporary is HWTS as a solution?

From what we've seen in the cases of large-scale distribution of HWTS products by Procter and Gamble and Vestergaard, such success relies upon a significant amount of external support for an extended period of time, indicating that, if such scale is to be maintained, it will require long-term, not short-term, commitment, not only from the parent companies but also from their partners, including the local government.

Additionally, we must consider that vulnerable populations are often the most difficult to reach with respect to centralized water distribution systems, and therefore, some may never be served in this manner. For these populations, HWTS might be considered a permanent solution as opposed to an interim solution, not unlike the reality for many rural households in the United States. In these ways, an interim solution begins to be stretched indefinitely, with implications for not only how it is discussed but also how it is planned for and carried out.

Specific to Ghana, scale-up is not happening quickly, to say the least. And even the challenges faced by the Government of Ghana with respect to rolling out the Strategy point to the need for long-term commitment – financial and otherwise – to achieve any amount of progress toward the ambitious goals set out in the Strategy. Additionally, to the extent that HWTS is being scale up in Ghana currently, it is not happening through commercialization. And in the instances of direct sales to consumers, these sales are to the middle class, not to the target vulnerable populations.

In short, the goals of providing safe water to vulnerable populations and achieving scale-up through commercialization often come in conflict, especially when considering the need to achieve coverage AND uptake to improve health. The case studies and policy development and roll out in Ghana point to a need for continued, long-term commitment from the government, donors and NGOs if HWTS is to be scaled up. And if this is the case, HWTS is likely not an interim solution but a long-term one. The conversation must shift to recognize this reality.

Appendices

Appendix A. Hunter 2009 RCT Publications

1. Brown, J.; Sobsey, M. D.; Loomis, D. Local drinking water filters reduce diarrheal disease in Cambodia: A randomized, controlled trial of the ceramic water purifier. *Am. J. Trop. Med. Hyg.* **2008**, *79*, 394–400.

2. Chiller, T. M.; Mendoza, C. E.; Lopez, M. B.; Alvarez, M.; Hoekstra, R. M.; Keswick, B. H.; Luby, S. P. Reducing diarrhoea in Guatemalan children: randomized controlled trial of flocculant-disinfectant for drinking-water. *Bull. World Health Organ.* **2006**, *84*, 28–35.

3. Clasen, T. F.; Brown, J.; Collin, S. M. Preventing diarrhoea with household ceramic water filters: assessment of a pilot project in Bolivia. *Int. J. Environ. Health Res.* **2006**, *16*, 231–239.

4. Clasen, T. F.; Brown, J.; Collin, S.; Suntura, O.; Cairncross, S. Reducing diarrhea through the use of household-based ceramic water filters: a randomized, controlled trial in rural Bolivia. *Am. J. Trop. Med. Hyg.* **2004**, *70*, 651–657.

5. Clasen, T.; Garcia Parra, G.; Boisson, S.; Collin, S.; Parra, G. G. Household-based ceramic water filters for the prevention of diarrhea: a randomized, controlled trial of a pilot program in Colombia. *Am. J. Trop. Med. Hyg.* **2005**, *73*, 790–795.

6. Conroy, R. M.; Meegan, M. E.; Joyce, T.; McGuigan, K. G.; Barnes, J. Solar disinfection of drinking water and diarrhoea in Maasai children: A controlled field trial. *Lancet* **1996**, *348*, 1695–1697.

7. Conroy, R. M.; Meegan, M. E.; Joyce, T.; McGuigan, K.; Barnes, J. Solar disinfection of water reduces diarrhoeal disease: an update. *Arch. Dis. Child.* **1999**, *81*, 337–338.

8. Crump, J. A.; Otieno, P. O.; Slutsker, L.; Keswick, B. H.; Rosen, D. H.; Hoekstra, R. M.; Vulule, J. M.; Luby, S. P. Household based treatment of drinking water with flocculant-disinfectant for preventing diarrhoea in areas with turbid source water in rural western Kenya: cluster randomised controlled trial. *Br. Med. J.* **2005**, *331*, 478–481.

9. Doocy, S.; Burnham, G. Point-of-use water treatment and diarrhoea reduction in the emergency context: an effectiveness trial in Liberia. *Trop. Med. Int. Heal.* **2006**, *11*, 1542–1552.

10. du Preez, M.; Conroy, R.; Wright, J. Use of ceramic water filtration in the prevention of diarrheal disease: a randomized controlled trial in rural South Africa and Zimbabwe. *Am. J. Trop. Med. Hyg.* **2008**, *79*, 696–701.

11. Kirchhoff, L. V; Mcclelland, K. E.; Pinho, M. D.; Araujo, J. G.; Desousa, M. A.; Guerrant, R. L. Feasibility and efficacy of in-home water chlorination in rural northeastern Brazil. *J. Hyg. (Lond).* **1985**, *94*, 173–180.

12. Luby, S. P.; Agboatwalla, M.; Hoekstra, R. M.; Rahbar, M. H.; Billhimer, W.; Keswick, B. H. Delayed effectiveness of home-based interventions in reducing childhood diarrhea, Karachi, Pakistan. *Am. J. Trop. Med. Hyg.* **2004**, *71*, 420–427.

13. Luby, S. P.; Agboatwalla, M.; Painter, J.; Altaf, A.; Billhimer, W.; Keswick, B.; Hoekstra, R. M. Combining drinking water treatment and hand washing for diarrhoea prevention, a cluster randomised controlled trial. *Trop. Med. Int. Heal.* **2006**, *11*, 479–489.

14. Lule, J. R.; Mermin, J.; Ekwaru, J. P.; Malamba, S.; Downing, R.; Ransom, R.; Nakanjako, D.; Wafula, W.; Hughes, P.; Bunnell, R.; et al. Effect of home-based water chlorination and safe

storage on diarrhea among persons with human immunodeficiency virus in Uganda. *Am. J. Trop. Med. Hyg.* **2005**, *73*, 926–933.

15. Maeusezahl, D.; Christen, A.; Pacheco, G. D.; Tellez, F. A.; Iriarte, M.; Zapata, M. E.; Cevallos, M.; Hattendorf, J.; Cattaneo, M. D.; Arnold, B.; et al. Solar drinking water disinfection (SODIS) to reduce childhood diarrhoea in rural Bolivia: a cluster-randomized, controlled Trial. *PLOS Med.* **2009**, *6*, e1000125.

16. Quick, R. E.; Kimura, A.; Thevos, A.; Tembo, M.; Shamputa, I.; Hutwagner, L.; Mintz, E. Diarrhea prevention through household-level water disinfection and safe storage in Zambia. *Am. J. Trop. Med. Hyg.* **2002**, *66*, 584–589.

17. Quick, R. E.; Venczel, L. V; Mintz, E. D.; Soleto, L.; Aparicio, J.; Gironaz, M.; Hutwagner, L.; Greene, K.; Bopp, C.; Maloney, K.; et al. Diarrhoea prevention in Bolivia through point-of-use water treatment and safe storage: A promising new strategy. *Epidemiol. Infect.* **1999**, *122*, 83–90.

18. Reller, M. E.; Mendoza, C. E.; Lopez, M. B.; Alvarez, M.; Hoekstra, R. M.; Olson, C. A.; Baier, K. G.; Keswick, B. H.; Luby, S. P. A randomized controlled trial of household-based flocculant-disinfectant drinking water treatment for diarrhea prevention in rural guatemala. *Am. J. Trop. Med. Hyg.* **2003**, *69*, 411–419.

19. Rose, a; Roy, S.; Abraham, V.; Holmgren, G.; George, K.; Balraj, V.; Abraham, S.; Muliyil, J.; Joseph, A.; Kang, G. Solar disinfection of water for diarrhoeal prevention in southern India. *Arch. Dis. Child.* **2006**, *91*, 139–141.

20. Semenza, J. A. N. C.; Roberts, L.; Henderson, A.; Bogan, J.; Rubin, C. H. Water distribution system and diarrheal disease transmission: a case study in Uzbekistan. *Am. J. Trop. Med. Hyg.* **1998**, *59*, 941–946.

21. Sobsey, M. D.; Handzel, T.; Venczel, L. Chlorination and safe storage of household drinking water in developing countries to reduce waterborne disease. *Water Sci. Technol.* **2003**, *47*, 221–228.

22. Stauber, C. E.; Ortiz, G. M.; Loomis, D. P.; Sobsey, M. D. M. D. A randomized controlled trial of the concrete biosand filter and its impact on diarrheal disease in Bonao, Dominican Republic. *Am. J. Trop. Med. Hyg.* **2009**, *80*, 286–293.

Appendix B. RCT Publications, 2009 - June 2014

1. Boisson, S.; Stevenson, M.; Shapiro, L.; Kumar, V.; Singh, L. P.; Ward, D.; Clasen, T. Effect of household-based drinking water chlorination on diarrhoea among children under five in Orissa, India: a double-blind randomised placebo-controlled trial. *PLOS Med.* **2013**, *10*, e1001497.

2. Du Preez, M.; Conroy, R. M.; Ligondo, S.; Hennessy, J.; Elmore-Meegan, M.; Soita, A.; McGuigan, K. G. Randomized intervention study of solar disinfection of drinking water in the prevention of dysentery in Kenyan children aged under 5 years. *Environ. Sci. Technol.* **2011**, *45*, 9315–9323.

3. du Preez, M.; McGuigan, K. G.; Conroy, R. M. Solar Disinfection of Drinking Water In the Prevention of Dysentery in South African Children Aged under 5 Years : The Role of Participant Motivation. *Environ. Sci. Technol.* **2010**, *44*, 8744–8749.

4. Fabiszewski de Aceituno, A. M.; Stauber, C. E.; Walters, A. R.; Meza Sanchez, R. E.; Sobsey, M. D.; de Aceituno, A. M. F.; Sanchez, R. E. M. A randomized controlled trial of the plastic-housing BioSand filter and its impact on diarrheal disease in Copan, Honduras. *Am. J. Trop. Med. Hyg.* **2012**, *86*, 913–921.

5. Firth, J.; Balraj, V.; Muliyil, J.; Roy, S.; Rani, L. M.; Chandresekhar, R.; Kang, G. Point-of-use interventions to decrease contamination of drinking water: a randomized, controlled pilot study on efficacy, effectiveness, and acceptability of closed containers, Moringa oleifera, and in-home chlorination in rural South India. *Am. J. Trop. Med. Hyg.* **2010**, *82*, 759–765.

6. Jain, S.; Sahanoon, O. K.; Blanton, E.; Schmitz, A.; Wannemuehler, K. A.; Hoekstra, R. M.; Quick, R. E. Sodium dichloroisocyanurate tablets for routine treatment of household drinking water in periurban Ghana: a randomized controlled trial. *Am. J. Trop. Med. Hyg.* **2010**, *82*, 16–22.

7. Luoto, J.; Mahmud, M.; Albert, J.; Luby, S.; Najnin, N.; Unicomb, L.; Levine, D. I. Learning to dislike safe water products: results from a randomized controlled trial of the effects of direct and peer experience on willingness to pay. *Environ. Sci. Technol.* **2012**, *46*, 6244–6251.

8. Luoto, J.; Najnin, N.; Mahmud, M.; Albert, J.; Islam, M. S.; Luby, S.; Unicomb, L.; Levine, D. I. What point-of-use water treatment products do consumers use? Evidence from a randomized controlled trial among the urban poor in Bangladesh. *PLoS One* **2011**, *6*.

9. McGuigan, K. G.; Samaiyar, P.; du Preez, M.; Conroy, R. M. R. M.; Preez, M. Du. High compliance randomized controlled field trial of solar disinfection of drinking water and its impact on childhood diarrhea in rural Cambodia. *Environ. Sci. Technol.* **2011**, *45*, 7862–7867.

10. Mengistie, B.; Berhane, Y.; Worku, A. Household water chlorination reduces incidence of diarrhea among under-five children in rural Ethiopia: a cluster randomized controlled trial. *PLoS One* **2013**, *8*, e77887.

11. Stauber, C. E.; Printy, E. R.; McCarty, F. a; Liang, K. R.; Sobsey, M. D. Cluster Randomized Controlled Trial of the Plastic BioSand Water Filter in Cambodia. *Environ. Sci. Technol.* **2011**.

12. Stauber, C. E.; Kominek, B.; Liang, K. R.; Osman, M. K.; Sobsey, M. D. Evaluation of the impact of the plastic BioSand filter on health and drinking water quality in rural Tamale, Ghana. *Int. J. Environ. Res. Public Health* **2012**, *9*, 3806–3823.

13. Tiwari, S.S. K.; Schmidt, W.P.; Darby, J.; Kariuki, Z. G.; Jenkins, M. W. Intermittent slow sand filtration for preventing diarrhoea among children in Kenyan households using unimproved water sources: randomized controlled trial. *Trop. Med. Int. Heal.* **2009**, *14*, 1374–1382.

Appendix C. Establishing and Mapping Collection of Literature

Generation of Collection of Literature

To establish the collection of literature around the 35 RCT publications consisting of Cited References and Citing Articles, I first generated a stand-alone text file for each RCT publication, with all of the fields and entries necessary to identify, map and analyze the references within the collection of literature. For a given RCT publication, the file generated from SCOPUS contained not only the RCT publication's record but also the records for all of the Citing Articles. A complete record included the following information:

- Basic bibliographic information: authors, title, journal, year, volume, issue number, author affiliation
- Abstract
- Keywords
- References
- ISSN[s] and DOI[t]
- Document type

Full records were present for RCT publications and for Citing Articles, but only basic citation information (see the information presented in the example below) was included for Cited References. Critically, the DOI for a Cited Reference was rarely available from the reference section of a RCT publication or Citing Article.

[s] An ISSN (International Standard Serial Number) is an 8-digit code used to identify both print and electronic media, including journal articles. (www.issn.org)
[t] A DOI (Digital Object Identifier) is a serial code used to uniquely identify objects, including journal articles. (www.doi.org)

The file generation was performed in SCOPUS and not in WOS primarily because SCOPUS presents the references cited in a form that contains all information necessary to identify and link up the reference to other instances that it is cited, whereas WoS does not. (WOS outputs the references cited in an abbreviated format that makes this identifying and linking process more difficult.) One of these critical pieces of information is the full title of the reference, as needed for keyword searching of titles and later textual analysis. For example, one of the 35 RCT publications was a 2013 article by Boisson et al. published in PLoS Medicine entitled "Effect of household-based drinking water chlorination on diarrhoea among children under five in Orissa, India: a double-blind randomised placebo-controlled trial." When this article was a cited reference of another article in the collection, it showed up as:

- **SCOPUS:** Boisson, S., Stevenson, M., Shapiro, L., Kumar, V., Singh, L.P., Effect of household-based drinking water chlorination on diarrhoea among children under five in Orissa, India: a double-blind randomised placebo-controlled trial (2013) PLoS Med, 10, pp. e1001497.
- **WOS:** Boisson S, 2013, PLOS MED, V10, DOI 10.1371/journal.pmed.1001497.

Textual Analysis

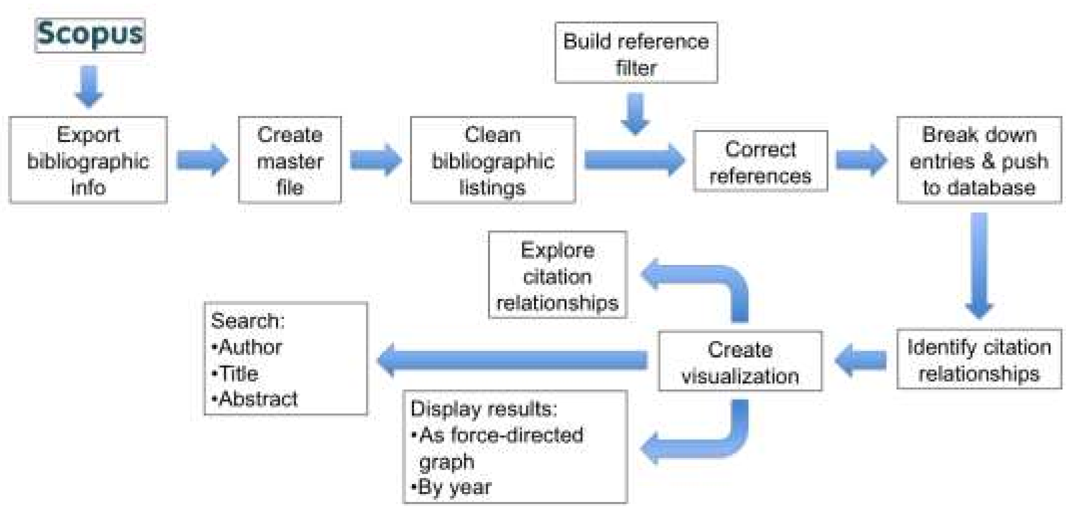
I was also able to perform a basic textual analysis of the titles and abstracts of the 35 RCTs and their citing references, as I had this textual content in the files generated for each of these publications. For this analysis, my collaborator Chris Kelley[u] first wrote a

[u] Johns Hopkins University doctoral candidate Chris Kelley

simple code to count instances of use, excluding articles, pronouns, prepositions and other identified words that were not content-specific. This produced 43 pages of words accompanied by the number of times they were each used throughout the titles and abstracts. I then manually scanned the words and created word groups for the four different types of evaluation – efficacy, effectiveness, public health impact, and behavior change – as well as for the 5 HWTS options. Kelley then wrote another simple code to go through the titles and abstracts to count instances of use of each word within a word group and tag each instance to the publication year. The output of this code was the number of instances of use, by year, for each word group.

Visualization of Collection of Literature

Having established the necessary set of files, I then worked with Kelley to create a user-friendly visualization of the body of literature contained in these files using the platform d3.js.[v] The steps in the process of generating the visualization are presented as a flow diagram in



[v] D3.js is a JavaScript library used to visualize data (https://d3js.org)

Figure 20 below. An extensive amount of time was spent turning the bibliographic information in the master file into clean, correct bibliographic listings that could then be searched to identify duplicate references with slight differences and merge these duplicate references. This automated process was not perfect, however, so additional manual cleaning was required. Further, because the DOI was not available for all Cited References, it was not a simple process to link up the RCTs and Citing Articles to the instances in which they were cited by other publications in the collection. This made identifying the citation relationships a more time- and manpower-intensive process than anticipated.

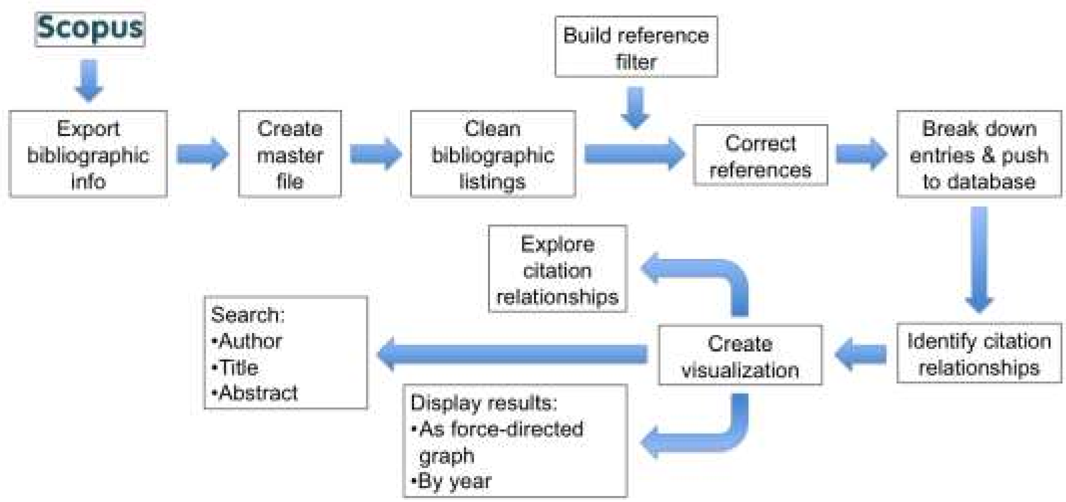


Figure 20. Flow diagram of generating visualization

Using the d3.js platform, the default visualization of the collection of literature took the form of a force directed graph, as seen in below. In a force directed graph, the "charge" of each node determines its interaction with the other nodes and therefore determines the distance between each node. Although it is tempting to read into the organization of this force-directed graph, the "charge" of each node and its interaction with its neighbors was predetermined by the software platform and is not indicative of relationships. In future versions of this visualization, it would be possible to have the charge of the node be determined by some characteristic of the node or its relationship with the node on the other side of the connection.

In the visualization shown in

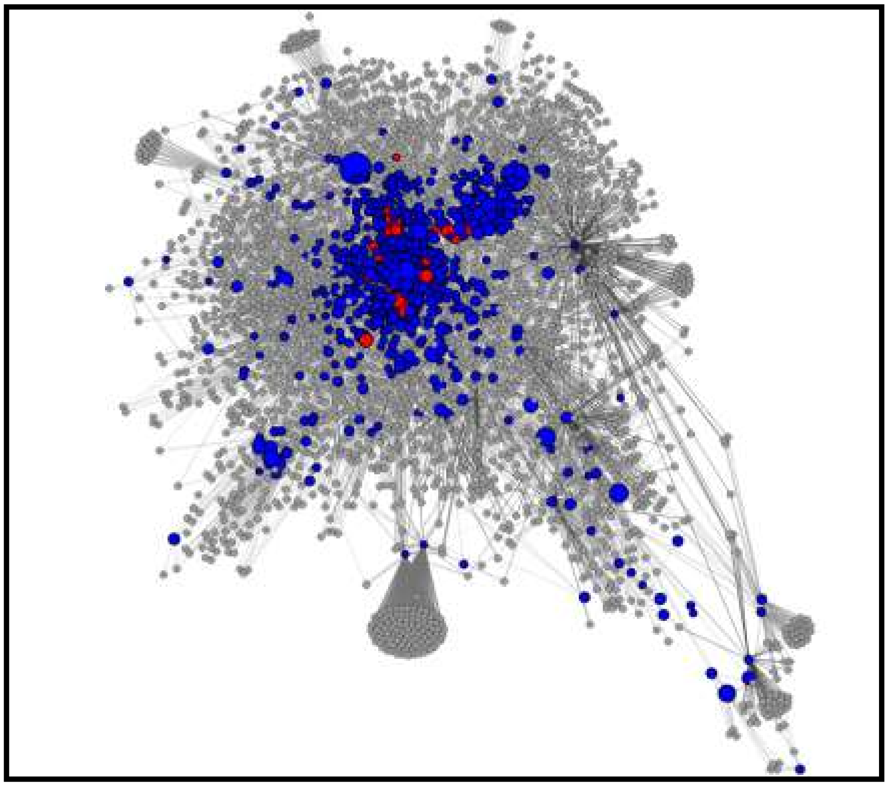


Figure 21 below, red nodes are the 35 RCT publications, blue nodes are the 600 Citing Articles, and grey nodes are Cited References. The 2,536 grey nodes shown do not represent the entire collection of Cited References. Because of the massive number of Cited References in this collection, we chose to clean up the visualization by only showing Cited References that were cited by at least two RCTs and/or Citing Articles. In this visualization, the size of the red RCT nodes and blue Citing Article nodes is scaled according to Times Cited in SCOPUS. The size of the grey Cited References is set, not scaled, as we did not have information on Times Cited for these publications.

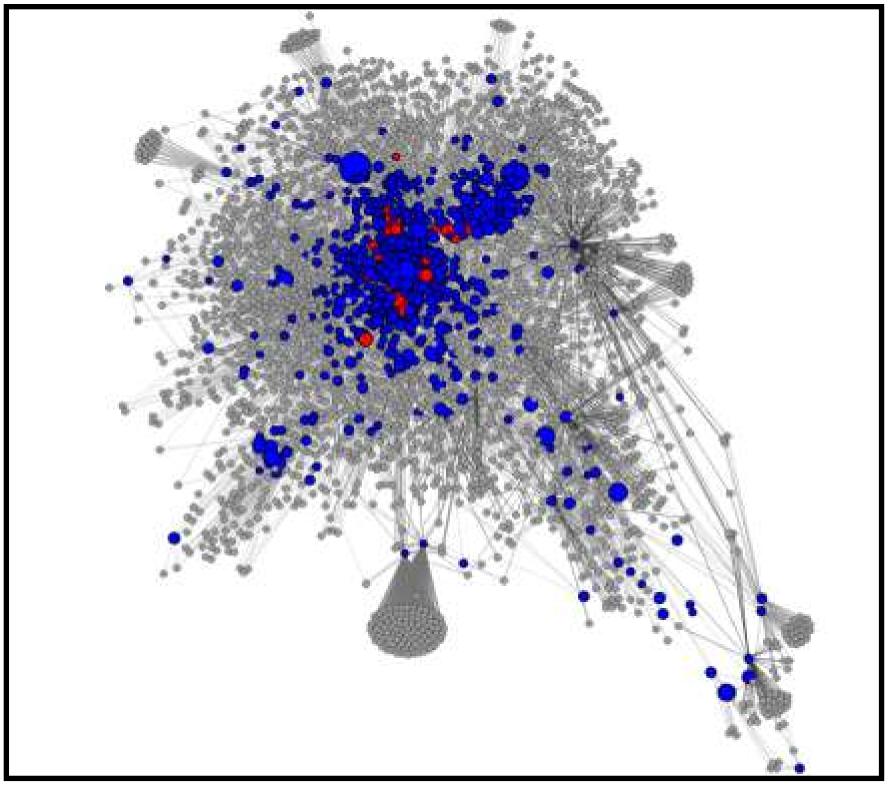


Figure 21. Force directed graph of collection

Examples of the relationships between the three types of nodes are shown in Figure 22 below, which has publications organized by time vertically. This example does not show all of the connections that each node has to the collection, just enough to show examples of the different relationships. It was not possible to connect Cited References to each other or to RCTs and Citing Articles because the information needed to make those connections was not available in the output files from SCOPUS. Including this information would have required searching for each of the >2,500 Cited References individually and generating files for each of them – a time-prohibitive endeavor.

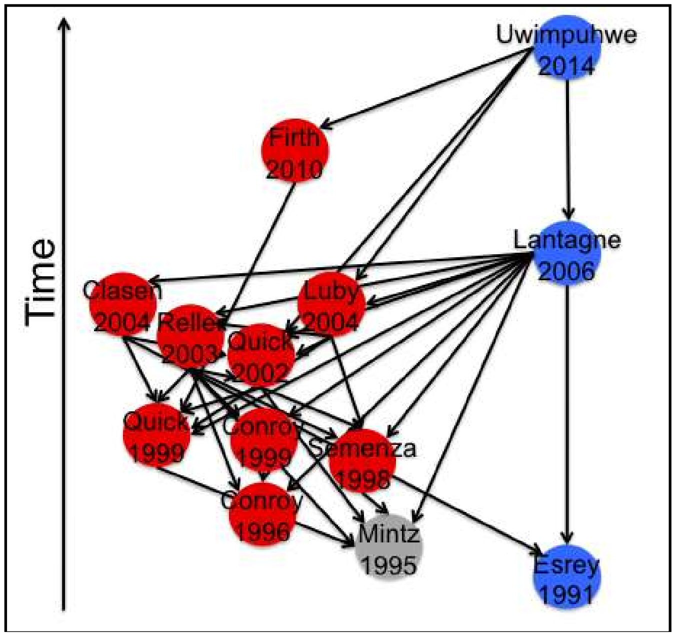


Figure 22. Examples of relationships between RCTs, Citing Articles, and Cited References

As noted above, location of nodes has little meaning in the force-directed format of the default visualization created by dj.3s. A more useful way of visualizing the collection is when it's organized by publication date. For this collection, that meant arranging the collection starting with the first publication date of 1877 (Downes et al. 1877) through to June 2014. In addition to ordering by publication date, one is also able to do a simple author or keyword search, making it easy to find publications of interest.

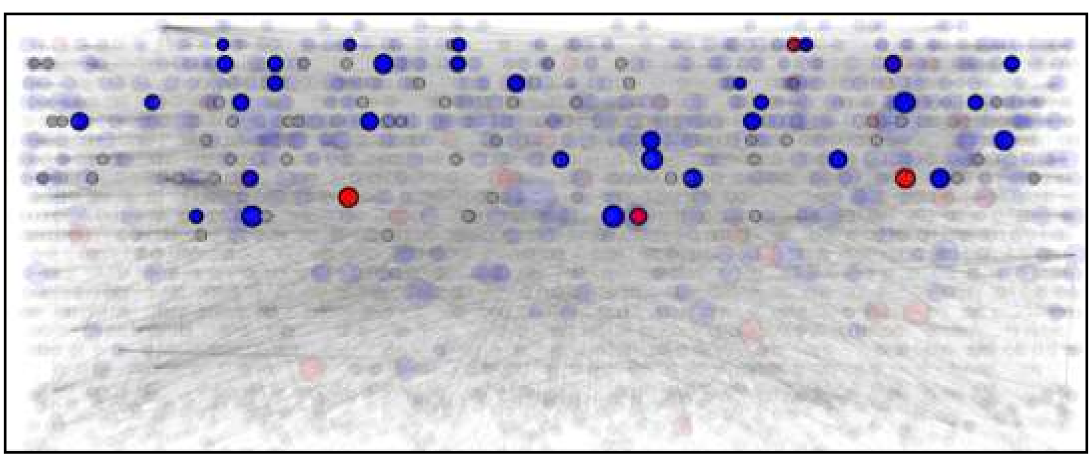


Figure 23 below shows an author search for Clasen in a time-oriented version of the visualization, with the arrow on the side showing time, from oldest publication on the bottom to youngest at the top (although this screenshot is cropped at the bottom, so it doesn't include all publications). You can see in this image that Clasen publications (nodes identified by solid color with no transparency) fall into all three categories of publications present in the collection – RCT publication, Citing Article and Cited Reference.

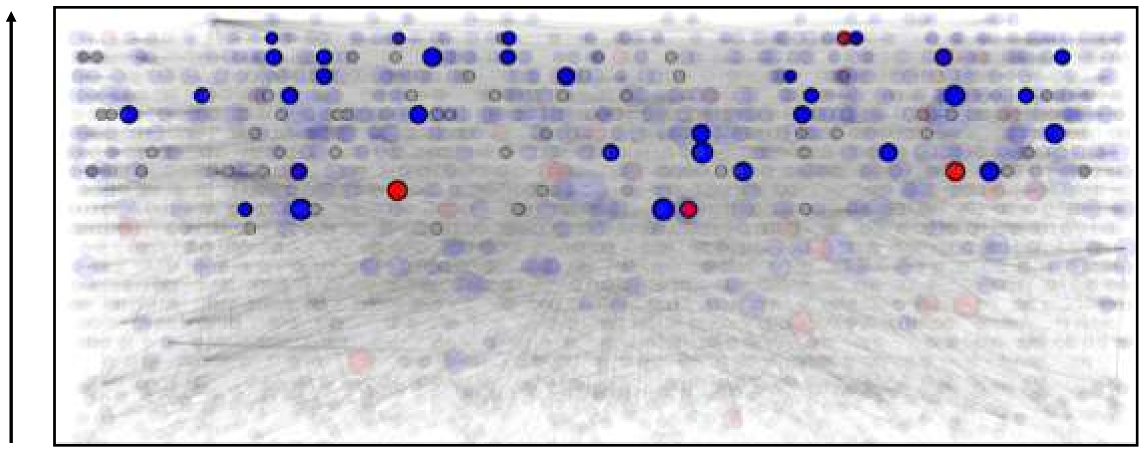


Figure 23. Author Search: Clasen (cropped visualization)

Given the size of the collection and the many connections shared among the thousands of publications, it was helpful to be able to explore the connections to a specific publication while muting the publications that are not connected. Therefore, we gave the user the capability to select a specific node by clicking on it to highlight the connections to that node while at the same time fading the other nodes and their connections. The connections of a publication to its Citing Articles and Cited References are well exemplified in Figure 24 below, which is a time-ordered (see arrow) visualization of Fewtrell et al. 2005 and its connections to its Cited References (below) and Citing Articles (above). These three user capabilities – ordering by publication date, searching for author or keyword, and highlighting connections – facilitated the exploration of prominent publications and their relationship with other publications in the collection.

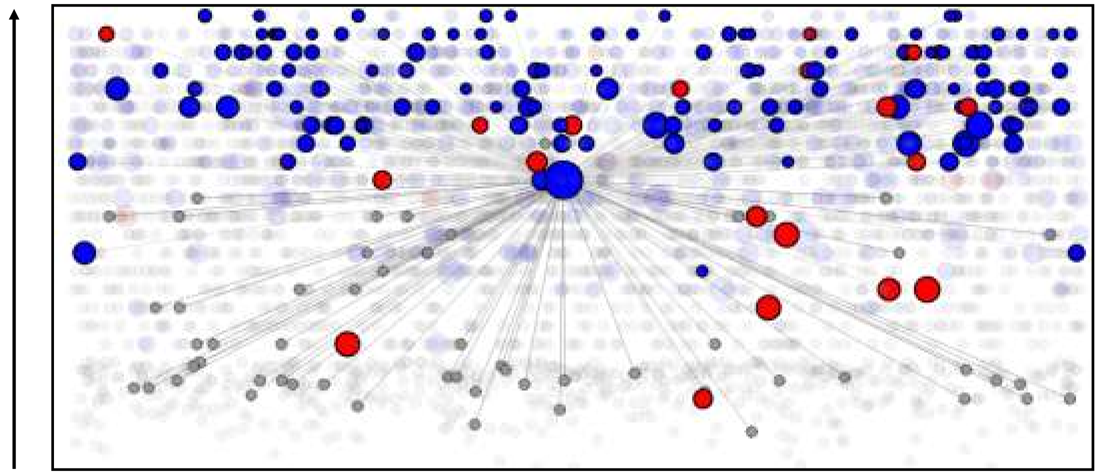


Figure 24. Fewtrell et al. 2005 (cropped visualization)

Appendix D. Practice-focused Interviews

Date	Interviewee	Company/Organization	Position
12/10/09	Jim Bodenner	Safe Water Team	Founder
12/11/09	Melinda Foran	CAWST	International Technical Advisor
1/5/10	Jim Bodenner	Safe Water Team	Founder
1/21/10	Rachael Paulson	Hands on the World Global	Founder
1/29/10	David Manz	University of Calgary	Professor
3/4/10	Frank Olesen	Vestergaard Frandsen	Regional Director, South Africa
3/5/10	Michael Steen Lunde	Vestergaard Frandsen	Regional Director, West Africa
7/30/10	Michael Steen Lunde; Araba Sam Annan	Vestergaard Frandsen	Regional Director, West Africa; Area Manager, Public Health
9/27/10	Christina Keller	Cascade Engineering, Triple Quest	Project Manager for Hydraid
9/29/10	Michael Steen Lunde	Vestergaard Frandsen	Regional Director, West Africa
11/12/10	Ken Conrad	Amway, Access Business Group	Senior Research Scientist
11/15/10	Michael Gately	Medentech, Aquatabs	Head of Sales and Marketing
12/9/10	Michael Steen Lunde	Vestergaard Frandsen	Regional Director, West Africa
1/6/11	Ken Conrad	Amway, Access Business Group	Senior Research Scientist
1/28/11	Paul Chen	Vestergaard Frandsen	Regional Director, DC Office
3/24/11	Christina Keller	Cascade Engineering, Triple Quest	Project Manager for Hydraid
3/24/11	Jim Bodenner	Safe Water Team	Founder
3/24/11	Ken Conrad	Amway, Access Business Group	Senior Research Scientist
5/27/11	Michael Steen Lunde	Vestergaard Frandsen	Regional Director, West Africa
6/24/11	Daniel Frauchiger	Vestergaard Frandsen, Lausanne	Head of Water Lab, Innovation Centre
9/26/11	Daniel Frauchiger	Vestergaard Frandsen, Lausanne	Head of Water Lab, Innovation Centre
2/17/12	Daniele Lantagne	Harvard University, Center for International Development	Giorgio Ruffolo Research Fellow
2/27/12	Susan Murcott	MIT, CEE; Pure Home Water	Senior Lecturer; Founder
3/2/12	Christine Stauber	Georgia State University, Institute of Public Health	Assistant Professor
6/4/12	Michael Steen Lunde	Vestergaard Frandsen	Regional Director
6/5/12	Beth Devroy	Ghanapreneurs	Founder
9/6/12	Beth Devroy	Ghanapreneurs	Founder
9/20/12	Jonas Jabulo	Ghana Water Company Limited	Chief Water Quality Manager
9/6/12	Pius Abuntori	Ghanapreneurs	Manager - Operations
9/11/12	Beth Devroy	Ghanapreneurs	Founder

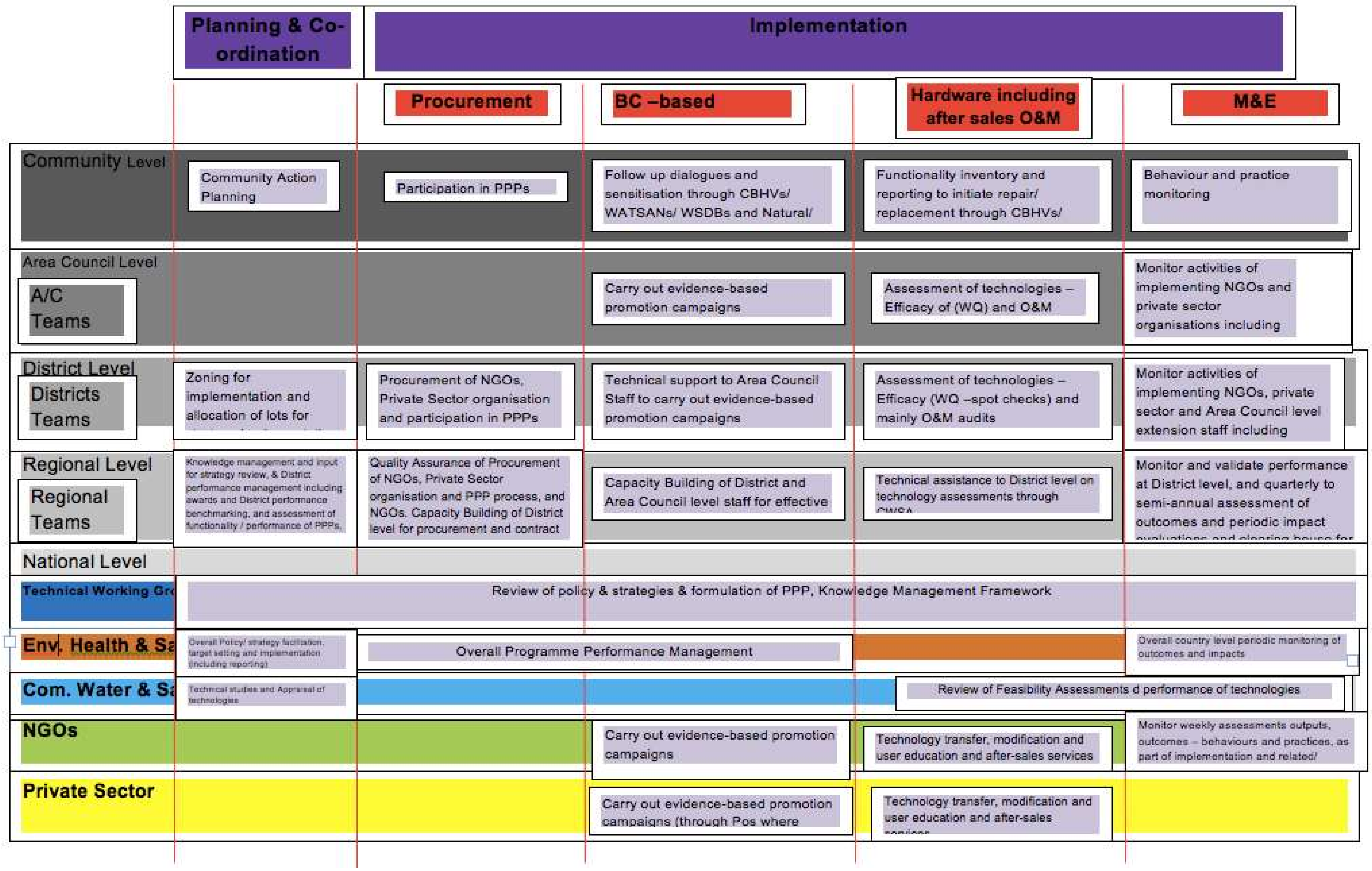
9/11/12	Beth Devroy; Pius Abuntori	Ghanapreneurs	Founder; Manager
10/4/12	Peter Tamakloe	Ceramica Tamakloe	Founder
10/8/12	Michael Steen Lunde; Araba Sam Annan	Vestergaard Frandsen	Regional Director, West Africa; Business Development Manager
11/14/12	Osman	Safe Water Team	Consultant
11/20/12	Beth Devroy; Dave Devroy	Ghanapreneurs	Founder; Technical Support
11/20/12	Josephus Hallie	Hydraid Distribution Center, Tema	Manager
11/21/12	Mary Kay Jackson	Pure Home Water	Managing Director
4/26/13	Susan Murcott	Pure Home Water	Founder, Director
8/27/13	Mary Kay Jackson	Pure Home Water	Managing Director
11/1/13	Ben Grostic	Triple Quest	Project Associate
11/7/13	Emily Smith	impactcarbon	Program Manager
3/14/14	Rob Quick	CDC	Medical Epidemiologist, Foodborne and Diarrheal Branch
3/19/14	Rob Quick	CDC	Medical Epidemiologist, Foodborne and Diarrheal Branch
11/20/14	Megan Grzybowski	Triple Quest	WASH Specialist
12/17/14	Kevin O'Callaghan	Medentech, Aquatabs	Sales & Marketing Manager

Appendix E. Policy-focused Interviews

Date	Interviewee	Company/Organization	Position
6/9/11	Yaw Sarkodie	Water and Sanitation Monitoring Platform	Team Leader
6/13/11	Joseph Ampofo	CSIR, Water Research Institute	Microbiology, Head
6/4/12	Michael Steen Lunde	Vestergaard Frandsen	Regional Director
6/5/12	Beth Devroy	Ghanapreneurs	Founder
9/17/12	Kweku Quansah	Environmental Health and Sanitation Directorate, Ministry of Local Government and Rural Development	Programme Officer
9/18/12	Marieke Adank	IRC International Water and Sanitation Centre	Programme Officer, Africa Team
9/20/12	Jonas Jabulo	Ghana Water Company Ltd.	Chief Water Quality Manager
9/24/12	Joseph Ampofo	CSIR, Water Research Institute	Director
10/2/12	Yaw Sarkodie	Water and Sanitation Monitoring Platform	Team Leader
10/4/12	Peter Tamakloe	Ceramica Tamakloe	Founder
10/5/12	Marion Kyomuhendo		Consultant to UNICEF
10/8/12	Michael Steen Lunde; Araba Sam Annan	Vestergaard Frandsen	Regional Director, West Africa; Business Development Manager
10/8/12	Patrick Apoya	Skyfox, Ltd.	Founder, Former Executive Secretary of CONIWAS
10/9/12	Frederick Addai; Patricia Buah	Water Directorate, Ministry of Water Resources, Works, and Housing	Director; WASH Specialist
11/6/12	Abu Wumbei	Resource Centre Network	Director/Coordinator
11/7/12	Harry Addor; Bansaga Saga	World Vision, Ghana	Grant Acquisition and Management Team Leader; WASH Advisor
11/12/12	Chelteau Barajei	UNICEF	WASH Officer
11/14/12	Osman	Safe Water Team	Consultant
11/21/12	Mary Kay Jackson	Pure Home Water	Managing Director
11/22/12	Samuel Amoako-Mensah	UNICEF	WASH Specialist
11/23/12	Ellen Gyekye	School Health Education Programme	Program Manager
11/27/12	Benedict Tuffuor	TREND Group, WASHTech	Program Officer
11/27/12	Steve Ntow	WASHealth Solutions	Founder
11/28/12	Sulaiman Issah-Bello	WaterAid	Programmes Manager
3/1/13	Michael Forson	UNICEF, NY HQ	WASH Specialist
8/27/13	Mary Kay Jackson	Pure Home Water	Managing Director
11/26/13	Daniele Lantagne	Tufts University	Assistant Professor

3/14/14	Rob Quick	CDC	Medical Epidemiologist, Foodborne and Diarrheal Branch
3/19/14	Rob Quick	CDC	Medical Epidemiologist, Foodborne and Diarrheal Branch
12/4/14	Benedict Tuffuor	TREND Group, WASHTech	Programme Officer
4/8/15	Hubert Charles	World Vision, Ghana	National Director
4/17/15	Harold Esseku	Rafa Consult	Consultant
4/22/15	Roshini George	Independent	Consultant to WHO

Appendix F. Scale-up Model Work Plan[23]



[23] Formatting and visibility of different text sections as presented in the Scale-up Model document

Vita

Laura MacDonald was born in Dallas, Texas, USA on July 7, 1986. She grew up in Dallas and graduated from the Episcopal School of Dallas in 2004. Laura received a B.S. in environmental engineering, with a minor in Spanish, from Northwestern University in 2008. She went on to pursue her Ph.D. in Geography and Environmental Engineering at the Johns Hopkins University, earning a M.S.E. in water and wastewater treatment processes in 2010 in the same department before completing her Ph.D. in 2017. Her research interests lie in the areas of household water treatment as a concept in the literature, as a product in the field, and as a policy at the national level. She focuses on Ghana, and specifically on the implementation of ceramic, biosand and membrane filters there, as well as the National Strategy for Household Water Treatment and Safe Storage. In August 2015, prior to completing her Ph.D., Laura joined the Research Learning Department at the Centre for Affordable Water and Sanitation Technologies in the role of Knowledge and Research Coordinator. She continues to work in that role today.

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